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Blunt Head Injury Protection for Paratroopers. Part II: Improved System Description

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Aircrew Protection Division

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13. ABSTRACT *(Maximum 200 words)*

Airborne operations regularly expose paratroopers to risk of head impact. Even relatively mild head impacts, while not life threatening, can cause short-term impairment from dizziness, headaches, memory loss, lack of ability to concentrate, and irritation. There may also be a cumulative traumatic brain injury (TBI) effect from repetitive head impacts compounding the sequelae. Given the necessity for speed and aggressiveness in the airborne operational environment, these symptoms become militarily significant, no matter how temporary, by jeopardizing soldier survivability and the success of the unit's mission. There is an obvious need to protect the soldier in these environments and reduce the head injury rate to a minimum. This test report provides the results of comparative laboratory assessments of seven candidate head protection systems compatible with the airborne configuration of the existing ballistic protective helmet, commonly known as the PASGT (Personnel Armor System for Ground Troops).

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Introduction

Parachutists, military and civilian, are regularly exposed to a variety of injury-producing mechanisms (Paschal et al., 1990). While not the most common site of injury, craniocerebral injuries are among the most severe when they do occur. The consequences of even moderately severe head injury to military paratroopers can be more dire than to their civilian counterparts—in addition to the immediate effects of the trauma, the survival of the airborne soldier on the battlefield can be dependent on his/her mental and physical agility immediately after landing. All parachutists generally wear head protection, in the form of a protective helmet. Since military paratroopers have a dominant concern for injury from ballistic sources (e.g., shrapnel, projectiles) during hostilities, their head protection consists of the standard Army ballistic helmet, slightly modified for paratrooper use. Concerns that these modifications do not provide adequate protection from the blunt impact hazards seen on the drop zone are substantiated by the continued incidence of head injuries to paratroopers.

In 1990, Paschal et al., reported that in the U.S. Army there were more than four serious closed-head injuries per month attributable to parachuting. At one large Army installation alone, Craig (1997) documented more than four emergency room visits per month due to parachuting-related head injury. In that series of visits approximately 20 percent of injuries were to the head. In one disastrous operation in 1982, five paratroopers were killed during a single night exercise—investigation revealed that all five had lost their helmets due to weaknesses in the helmet retention systems [U.S. Army Aeromedical Research Laboratory (USAARL), 1983].

The purpose of this research project was to determine whether recent advances in energy-attenuating materials could improve blunt injury protection for Army paratroopers, while maintaining protection against penetrating ballistic trauma. The project plan called for experimental helmet development and testing (Phase I), followed by a prospective cohort study evaluating the practical benefit of improved head protection on head injury rates. After consulting with key paratrooper unit personnel, several guidelines for the project were developed (Appendix A). First, any experimental helmet intended for use by operational paratroopers must retain the external appearance of the original Personnel Armor System for Ground Troops (PASGT). Second, the essential function of the PASGT helmet—ballistic protection—must be preserved. Third, any successful experimental helmet must be found acceptable for airborne (jump) use. A further constraint specified that, in order to be declared a success, an experimental helmet must be superior or equal to the current airborne PASGT, with regard to all critical safety parameters.

Part I (Trumble, McEntire, and Crowley, 2004) of this report reviewed various commercially available solutions that were procured and tested, but found to be unacceptable for various reasons. This report, Part II, describes two systems that demonstrated superior performance and were ultimately deemed acceptable for field-testing by the user.

Materials and methods

Test standards

There are a variety of published impact protection and retention design standards, each for a specific purpose, and with varying requirements and test methods. These standards were reviewed in an effort to determine which standards, if any, could be applied to the PASGT helmet when employed in airborne operations. Commercial test standards that were reviewed included those from the Snell Memorial Foundation (2000), the National Highway Traffic Safety Administration (NHTSA) (2000), and the American Society of Testing and Materials (ASTM) (1996 and 2000a - 2000i). Military test standards reviewed included the U.S. Army standards for flight helmets and ballistic helmets. It was determined that no published standard would adequately describe the blunt impact protection requirements for military parachutists. Therefore, it was decided to test the blunt impact and retention performance of the current issue paratrooper configuration against the performance of the candidate systems. By using the current system as a baseline, the testing would determine if a candidate system was better than the currently fielded system.

No helmet weight limitation standards could be located that pertained to helmets for a military parachutist or ground force soldier. Lacking a standard, the current issue System 2ecame the benchmark. In an effort to provide answers to system weight concerns, it was decided to weigh each of the helmet components and the complete helmets of each of the three configurations. A compilation of the weights is contained in Appendix D.

Candidate systems

Selection

In May 2001, USAARL placed a Commerce Business Daily (CBD) announcement (Appendix A) for industry to submit proposed helmet retention and impact protection systems. Initially, two companies [Gentex Corporation (Appendix B) and Oregon Aero (Appendix B)] submitted a total of six different candidate protective systems (the testing and evaluation of these systems are presented in Part I of this report.) As a result of initial testing and finding that none of the initial candidate systems provided better blunt impact protection than the issue PASGT, it was necessary to identify and test two additional hybrid systems. Ultimately these proved to be acceptable for further study and are the subject of this Part II report (Table 1). These systems, the Skydex nape pad with CGF Helmets' retention harness and the Oregon Aero pads with CGF Helmets' retention harness are referred to as System 2 and System 3, respectively, in this report. Medium and large PASGT helmet shells were used to mount the protective systems.

Table 1.
Candidate systems tested.

Helmet System	Description
1	Current airborne PASGT
2	Skydex nape pad with Parachutist Impact Liner (PIL) & CGF three-point retention harness
3	Oregon Aero pads & CGF three-point retention harness

Description

System 1: Airborne PASGT

The PASGT helmet is constructed of an aramid fiber shell and is fitted to the individual soldier with the appropriate suspension system (Figure 1). Five sizes are available: extra small, small, medium, large and extra large. The helmet shell itself (also known as, "Kevlar®," "K-pot," or "Helmet, Ground Troops Parachutists") is procured against its formal military specification, MIL-H-44099A (Department of Defense, 1989). An adjustable headband is used to fit to the helmet (Figure 2a and 2b). The helmet is retained to the soldier's head by a chinstrap with two adjusting buckles and a pull-the-dot snap fastener (Figure 3). The System 1 configuration includes a retention system or strap (Figure 4) and a vinyl nitrile foam nape pad (Figure 5). Both the retention strap and nape pad are "one size fits all." The suspension system is adjustable for head shape (Figure 1). A comfort donut pad (Figure 6) is often installed for user comfort, but does not provide any impact attenuation. All testing was conducted with the comfort donut pad installed due to its popularity with soldiers. National stock number information for the components of the current 'Airborne PASGT' is presented in Appendix L. Details of the 'Airborne PASGT' configuration are contained in Appendix E.

System 2: Airborne PASGT with Skydex® nape pad, PIL and CGF three-point retention harness

System 2 (Appendix I) consisted of the PASGT helmet shell, the issue suspension and headband fitting systems in System 1. Also featured were the current issue PIL (Figure 7) in the frontal and crown areas, a three-point retention harness by CGF Helmets (Figure 8) and a 50 mil size nape pad by Skydex® Cushioning Technologies (Figure 9).

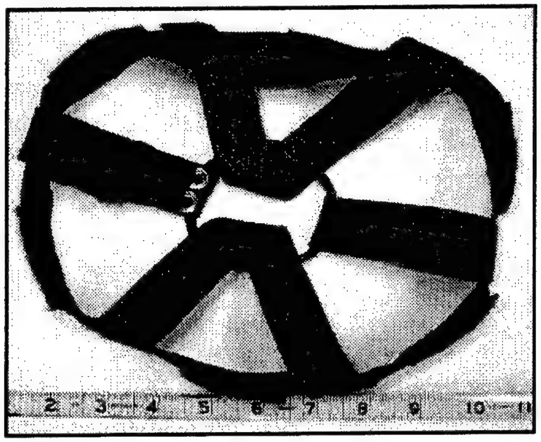
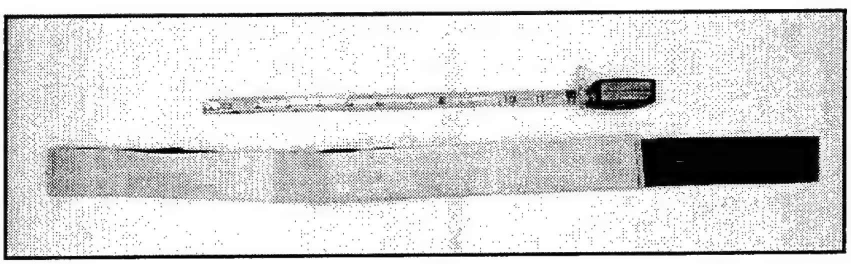
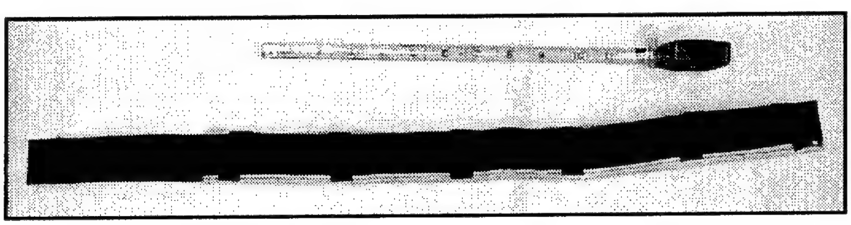


Figure 1. Suspension.



(a)



(b)

Figure 2. Current issue leather headband. (a) Head side view. (b) Helmet side view.

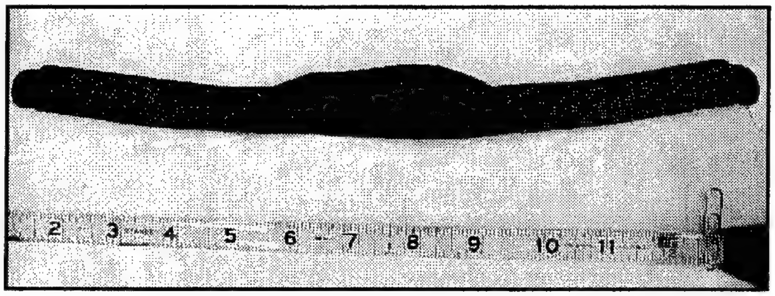


Figure 3. Chinstrap.

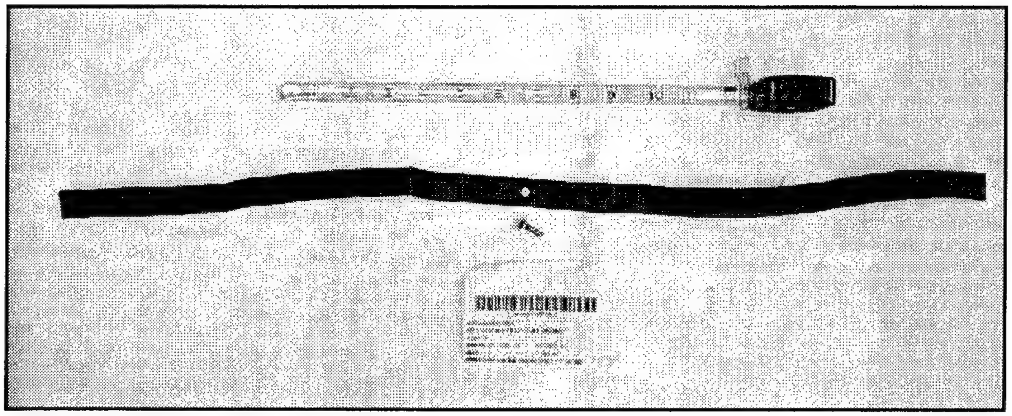


Figure 4. Retention strap.

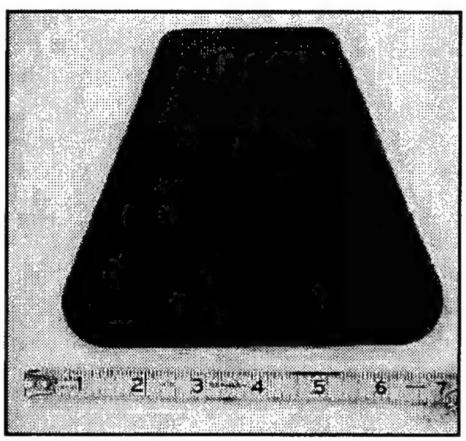


Figure 5. Nape pad.

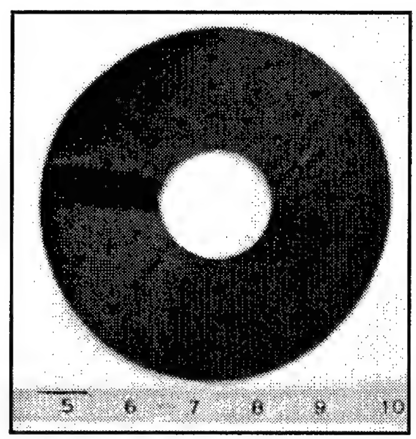


Figure 6. Comfort donut pad.

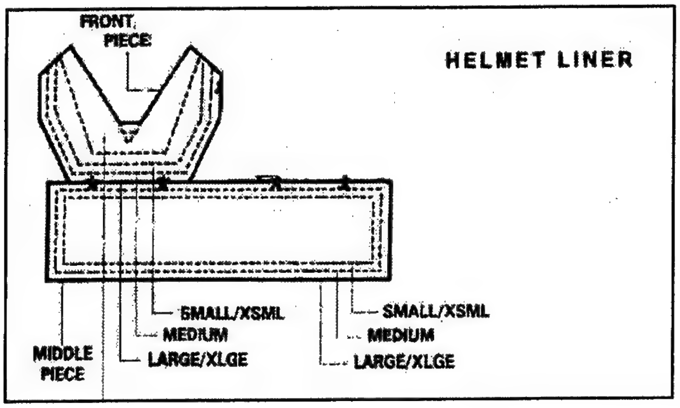


Figure 7. Current issue impact liner, parachutist (PIL).

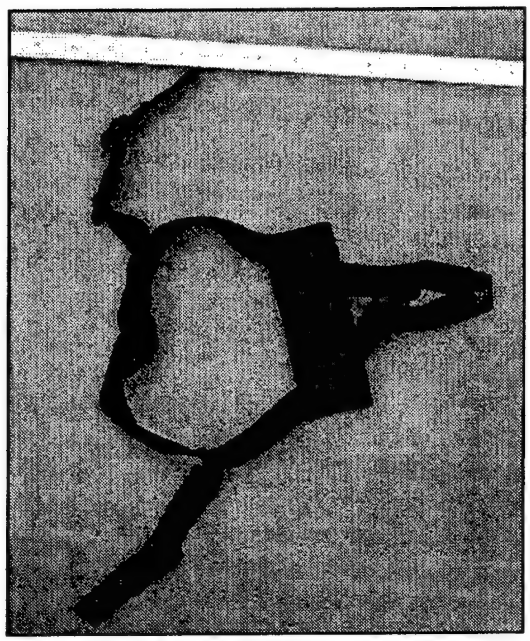


Figure 8. CGF Helmets' 3-point harness.

The Skydex® Cushioning Technologies nape pad was similar in overall dimensions and fastening method as the current issue impact attenuating nape pad used in System 1. The Skydex® pad was constructed of a 50 mil polymer material, with a series of cups placed back to back within the shell. The pad was attached to the PASGT through an opening in the pad, and was secured to the helmet shell with a locking screw and T-nut. The Skydex® nape pad provided coverage in the occipital aspect of the skull, a prime area of impact during a poorly performed Parachutist Landing Fall (PLF). In this design, the PIL provided enhanced impact protection in the frontal and parietal regions.

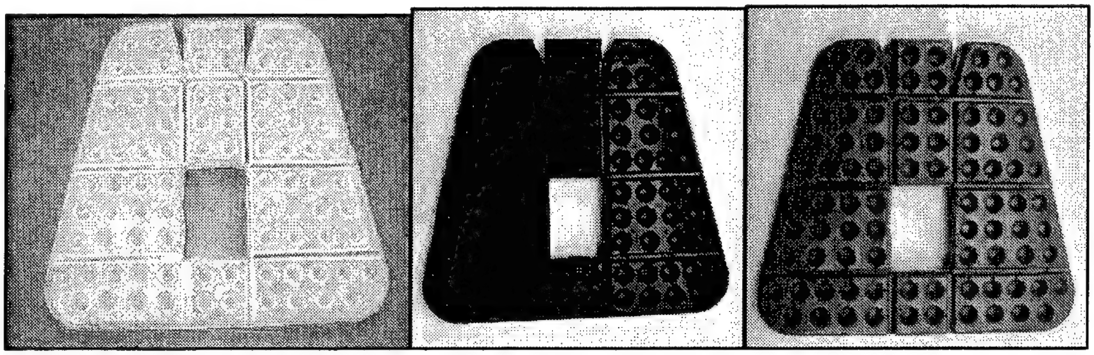


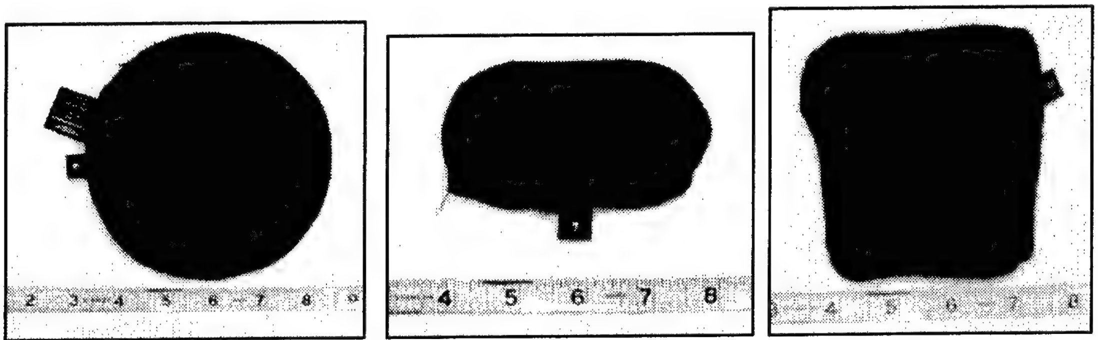
Figure 9. Skydex® 50 mil nape pad (black & gray colors proposed for field trial).

The CGF Helmets Inc. three-point retention harness was constructed of a 20 mm (0.787 in) wide polyester and cotton webbing. Fitting, adjustment and securing of the system was accomplished through the use of four polymer adjustment buckles and a polymer quick-release fastener. The adjustment buckles, Model LK20E (Appendix F), and the quick release fastening buckle, Model LB20R (Appendix F) were manufactured by YKK (Appendix B). The harness was fastened to the inside aspect of the helmet at the rear and forward side holes with T-nuts and 5/8" slotted, truss head locking screws. Detailed installation instructions of the CGF Helmets three-point retention harness are contained in Appendix G for the System 2 helmet and Appendix H for the System 3 helmet (discussed below). Detailed assembly instructions for the System 2 helmet are contained in Appendix G.

System 3: Airborne PASGT with Oregon Aero pads and CGF three-point retention harness

System 3 (Appendix J) consisted of the standard PASGT shell fitted with pads manufactured by Oregon Aero and a three-point retention system manufactured by CGF Helmets. The pads provided impact attenuation and increased comfort, and are similar to the pads used in the Modular Integrated Communications Helmet (MICH) being fielded by Special Forces Soldiers. The three-point retention system provided improved retention and helmet stability.

The Oregon Aero pads consisted of cloth covered, dual density visco-elastic foam pads coated with a waterproof, air permeable coating. These fabric-covered pads were fastened to the inside aspect of the helmet with hook and loop fastener material. The pad used two dissimilar fabrics so only one side would adhere to the hook and loop fastener material. A circular pad (#6 size, Figure 10a) was placed in the crown to provide protection for the parietal region. Four oval pads (Figure 10b) were placed along the coronal plane (two on each side). To provide further protection at the rear, one oval pad was placed between the crown pad and the two trapezoidal pads (Figure 10c) that cover the occipital area; another trapezoidal pad was placed to protect the front of the skull. The pads were intended to be easy to install, remove, replace, withstand multiple impacts and be suitable for airborne operations.



(a) (b) (c)

Figure 10. Oregon Aero fitting pads. (a) Crown pad. (b) Oval pad. (c) Trapezoidal pad.

The CGF Helmets' three-point retention harness was described previously, as it is also used in System 2. Detailed assembly instructions for the System 3 helmet are contained in Appendix H.

Impact attenuation

All impact tests were conducted using the USAARL vertical monorail drop tower (Figure 11). This guided, free fall drop tower conforms to ANSI Z90.1 (1992). The test headform was the size 'C' (medium) headform defined by ANSI Z90.1-1992. The hemispherical [1.9 inch (48.26 mm) radius] impact anvil was used for all helmet impact tests. The majority of head injuries during parachute operations occur during the landing phase; and of these, the impact surfaces most commonly encountered are drop zone obstacles such as rocks, tree limbs and logs (Paschal et al., 1990). USAARL's rationale for the hemispherical anvil was that it would best simulate these potential drop zone hazards.

The same test headform (ANSI Z-90, size C) was used for tests involving both medium and large helmet sizes. This was felt to be acceptable because the headform circumference, length, and breadth measurements were between the two helmet sizes (e.g., an individual with these head measurements could wear either size helmet).

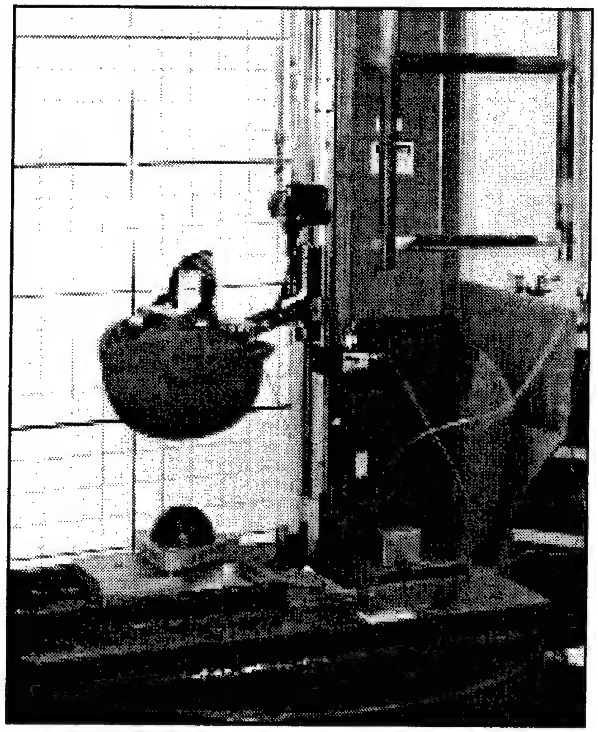


Figure 11. USAARL vertical monorail drop tower.

Four impact locations, deemed likely areas of impact associated with a poorly executed PLF, were tested. These sites were: the front, rear, left nape and right nape areas (Appendix K). The impact locations and headform orientations were derived from the U.S. Army Aviation and Troop Command (1995) Aircrew Integrated Helmet System Fabrication Specification (1680-ALSE-101) and the American National Standards Institute ANSI Z90.1b (1979) specifications. These impact sites are described by defining the headform orientation (Table 2).

Table 2.
Headform orientation by impact site.

	Head Pitch Angle (deg)	Head Roll Angle (deg)
Front	25	0
Rear	25	0
Left nape	90	20
Right nape	90	20

The test helmet was fitted to the headform and then released from appropriate heights that would result in target impact velocities of 10.0 (3.05 m/s), 14.14 (4.31 m/s) and 17.32 feet per second (fps) (5.28 m/s). Impact velocity was measured using a United States Testing Company

VS300 velocimeter. The velocimeter was set to record the velocity of the headform immediately prior to impacting the anvil.

Headform vertical deceleration was measured by a single-axis accelerometer affixed near the headform's center-of-mass. The accelerometer data were filtered via a low-pass filter with a four-pole Butterworth transfer function and a corner frequency of 1000 Hz, in compliance with Society of Automotive Engineers (SAE) recommended practice J211 (1995). Force sensors beneath the hemispherical impact anvil measured the impact.

Three pre- and post-impact tests were conducted for the purpose of ensuring monorail drop tower instrumentation integrity as per ANSI Z90.1b-1992. The procedure for these tests is as follows: The headform is mounted to the drop arm assembly and positioned at a 10-degree incline to the horizontal as for a crown impact (Figure 12). The standard size C magnesium headform and drop arm assembly was elevated and released from a height of 12 inches (0.3 m) where the crown area impacted a 1 inch (25mm) thick by 6 inches (150mm) in diameter, flat modular elastomer programmer (MEP) (Figure 12).

Figure 12. Modified headform oriented at 10° for the pre- and postcalibration crown impacts.

The average pre-test impact attenuation results (peak accelerations) were compared against the mean of the post-test impact attenuation results. Any difference greater than 10 percent was considered indicative of damaged instrumentation and voided all test results. The equipment

would be inspected and repairs made as necessary. The test series would then be repeated (U.S. Army Aviation and Troop Command, 1995).

Helmet dynamic stability

Helmet dynamic stability tests were conducted using the USAARL mini-sled (Figure 13) and high-speed video camera recording at a rate of 1,000 frames per second. Adequate illumination of the helmet/headform/sled assembly was provided by a Photographic Analysis Ltd. (Appendix B) Model Pallite VIII high intensity light. Further documentation of each test run was accomplished by video taping each test run in VHS format using a Panasonic AG-1960 multiplex videocassette recorder (Appendix B). The Hybrid II headform and the biodynamic Hybrid III neck (mounted to the sled) react to the acceleration by flexing in a similar manner as a human head and neck would in reaction to deceleration, such as parachute opening shock.

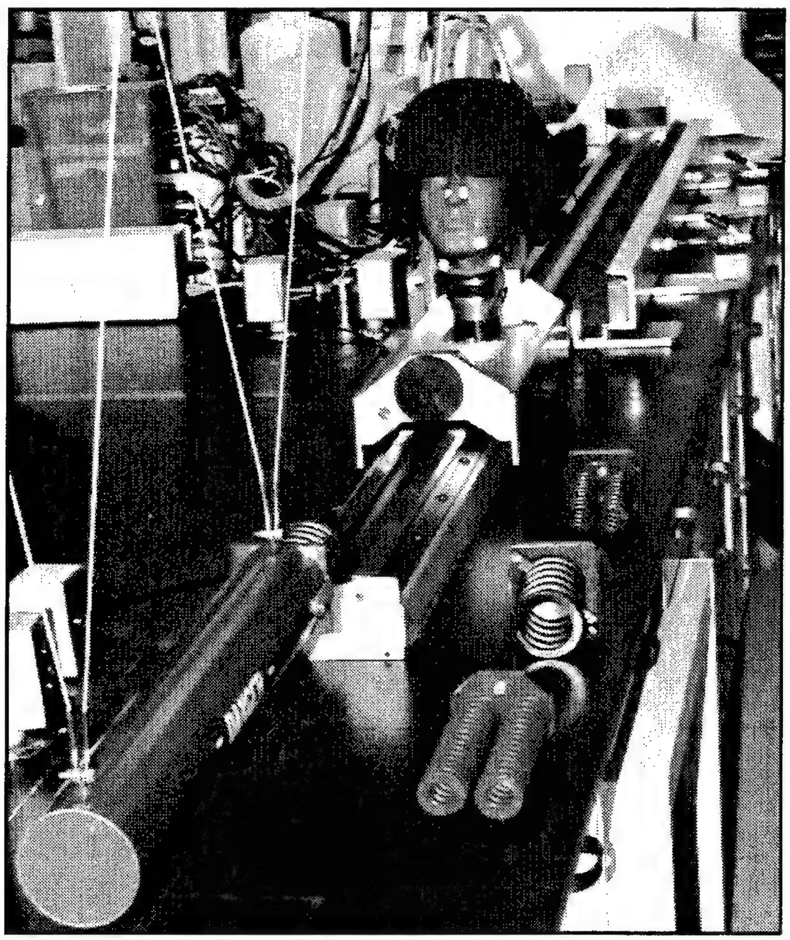


Figure 13. USAARL mini-sled test apparatus.

The sled/neck/head assembly has 19 measurable channels of electronic instrumentation, of which 16 channels are used. Data signals collected during the sled and headform acceleration events were conditioned using a Metraplex Corporation Series 300 multiplexed FM data system (Appendix B). These data signals are identified in Table 3.

Table 3.
Mini-sled electronic instrumentation.

Location	Parameter	Units	Axis	Data recorded
Sled	Acceleration	G	X	Yes
Lower neck (C7/T1)	Force	Pounds	X Y Z	Yes No Yes
Lower neck (C7/T1)	Moment	Inch-pounds	X Y Z	No Yes Yes
Upper neck (C1)	Force	Pounds	X Y Z	Yes Yes Yes
Upper neck (C1)	Moment	Inch-pounds	X Y Z	No Yes Yes
Head	Acceleration	G	X Y Z	Yes Yes Yes
Head	Angular rate	Degrees/second	X Y Z	Yes Yes Yes

In these tests, the helmet was fitted to the Hybrid II headform attached to a quasi-frictionless sled. The retention harness was fastened and then tightened until the helmet was snug on the headform. A 100-pound (45.36 kg) pendulum, with a helical spring attached to the impacting end, was then raised to the appropriate pulley on the wall. This position correlated to a vertical distance of 17 inches (432 mm) from the centerline of the pendulum to the centerline of the sled impact site. The pendulum was then released and swung down and forward by gravity to impact the sled. The helical spring provided an interface between the pendulum and the sled, controlling the acceleration pulse. The helical spring contacted the impact point on the sled and transferred energy that resulted in a sled acceleration of 33 G. During the acceleration phase, the sled traveled 35 inches (889 mm) then contacted a low friction braking system 84 inches (2134 mm) in length, which decelerated the sled to a stop. Following each test run, the retention harness was disconnected, the helmet removed, then either refit or another helmet system was fitted. This is a nondestructive test that allowed for repetitive testing of test assets. Three test

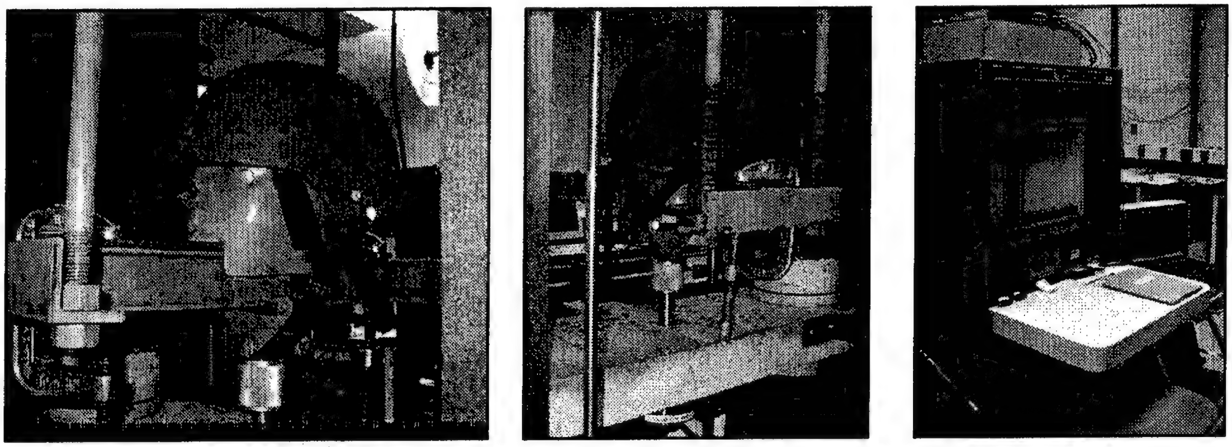
runs were conducted for each helmet resulting in nine runs in total being performed for the three helmet configurations.

Sled acceleration was measured with a single axis accelerometer located on the sled. The rotation of the helmet relative to the headform was tracked using reflective tape $^{13}/_{32}$-inch (10 mm) diameter, affixed to two points on the headform (nose and neck) and two points on the helmet (lower edge of the ear cup and the top edge of the PASGT). The high-speed video images were digitized and analyzed. The angular rotation of the helmet in relation to the headform was determined through the use of Kodak Motion Analysis Workstation (MAW) software (Appendix B).

Chinstrap strength and elongation

A Tinius-Olsen Inc. compression/tension test machine performed quasi-static tensile strength and elongation testing of the chinstrap (Appendix B) (Figure 14). Within the stationary frame of the compression/tension test machine, two vertical worm gears provided vertical motion to the crosshead. During testing, a T-Hydronics Inc. (Appendix B) 3,000-pound (13,345 N) capacity load cell measured the compressive or tensile loading. A headform was attached at the top of the stationary frame and a simulated chin was mounted on the load cell attached to the crosshead. The placement of the simulated chin complies with, ANSI Z90.1-1979 (1979). The velocity and linear vertical displacement of the crosshead relative to the stationary frame was measured via a Lucas Shaevitz (Appendix B), Magnarule Plus™ linear velocity displacement transducer (LVDT). The elapsed time was measured using a Cramer Controls (Appendix B) elapsed time indicator (ETI).

A PASGT helmet shell without suspension components was fitted with either the current issue chinstrap assembly (MIL-S-44091) and parachutist retention strap (NSN 8470-01-092-7524) (Appendix L) or the CGF Helmets' three-point retention harness. During the chinstrap strength test, no helmet liner was installed. By placing the helmet directly on the headform, there would be no compression of suspension components and all pull force would be through the chinstrap and PASGT attachment points. For the System 1 configuration, the free end of the chinstrap was placed around the simulated chin and fastened (Figures 14a and b), then the adjustment tabs were adjusted to ensure a snug fit. The retention straps were placed around the chinstrap in accordance with the paratrooper configuration instructions and affixed via the hook and loop material. For the System 2 & 3 configurations, the chinstrap of the CGF Helmets' three-point retention harness was placed around the simulated chin and fastened via the polymer quick release buckle. The adjustment tabs of the cloth webbing were pulled to ensure a snug fit.



(a) (b) (c)

Figure 14. Tinius-Olsen chinstrap strength test apparatus. (a) Front view pull test. (b) Rear view pull test. (c) Control station.

A preload of 25 pounds (111.2 N) force was applied to the strap and held for 30 seconds (zero position). The applied load was then increased gradually [0.5 in/min (1.27 cm/min)] until 250 pounds (1112 N) of force was reached (if the retention system remained intact). This load was then sustained for 30 seconds. Following this, the load was gradually increased at 0.5 in/min (1.27 cm/min) until 3,000 pounds (13,345 N), the load cell maximum capacity, was reached or a catastrophic failure of the retention assembly occurred. The achieved load was recorded, and the amount of chinstrap elongation was determined by subtracting the initial cross-head position from the final cross-head position.

Weight

Helmet components and completed systems were weighed using a Sartorius (Appendix B) Model LC12001P electronic balance with a maximum capacity of 423.3 ounces (12,000 grams). The Sartorius LC12001P was developed, manufactured and tested in compliance with ISO 9001 standards. Items were placed approximately on the center of the balance and the weight was read from the LED display and recorded.

Data analysis

Impact attenuation

For each helmet, peak accelerations were grouped by impact site and impact velocity. Means were calculated for the "back" impact sites (rear, left nape, and right nape areas) and for impact velocity. The tests appear to be more suited and reproducible for the improved configurations (Systems 2 and 3) that have definite impact-absorbing features than for the baseline PASGT

helmet that has only 'bump' protection from blunt force. The novel impact sites toward the posterior aspect of the helmets (e.g., rear, right, and left nape) appear particularly variable—for this reason, these three test sites were averaged. This presents a more balanced view of helmet performance at the important rear location. Impact test results were analyzed by comparing the peak accelerations measured in the test helmets to the performance of the currently issued military parachutist helmet.

Helmet dynamic stability

Helmet dynamic stability test results were analyzed by comparing the average angular displacement of each helmet relative to the headform. Positive displacements represented rearward rotations of the helmet. Negative displacements represented forward helmet rotation, or rotations in which the brow of the helmet rotates downward, toward the face and nose. From the peak forward and rearward helmet rotations, overall angular rotations were determined and compared. In general, the lower the overall angular rotation of the helmet, the better the performance of the helmet's retention system.

Chinstrap strength and elongation

Test results were analyzed by comparing the failure load and maximum elongation of the CGF Helmets three-point retention system to the issue chinstrap/retention harness. An improved retention system would display greater strength and reduced strap elongation than recorded from System 1.

Weight

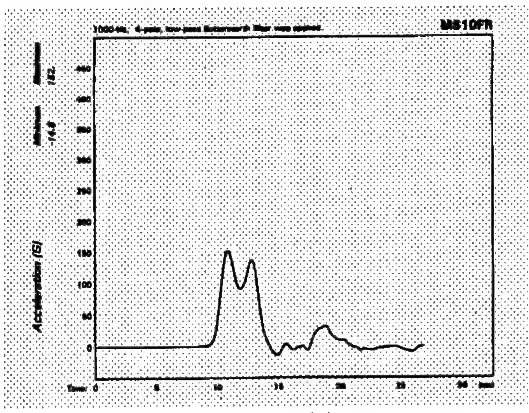
The weights of the candidate systems and components were compared to the weight of the currently issued system and its components. The lower the overall weight, the more desirable the system.

Results

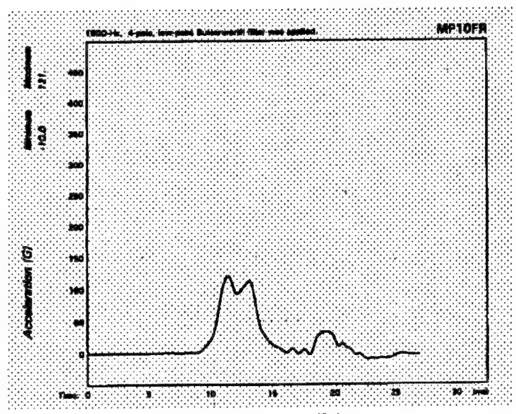
Impact attenuation

The peak acceleration values for all tests, at the three different impact velocities (10.0, 14.14, and 17.32 ft/s), using the medium and large PASGT helmets are provided in Tables 4 and 5. Examples of headform acceleration time history are provided in Figures 15 and 16. Comparison of the headform acceleration time history traces is located in Appendix M. Included with the results for each impact velocity cluster is the overall mean for all four-impact sites and the mean for the three rear impact sites (back). Also shown in Tables 4 and 5 is the measured change from baseline (System 1 helmet).

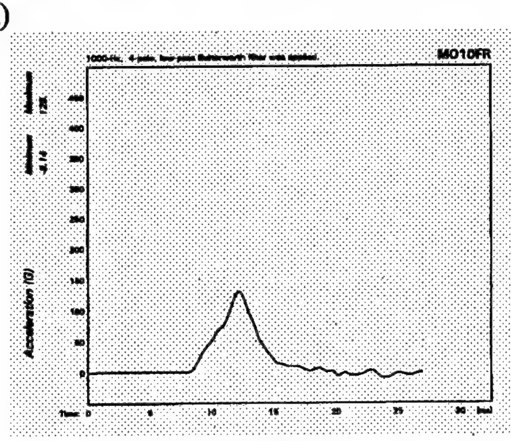
Despite four isolated tests in which baseline configurations appeared to perform better, impact performance (averaged for impact velocity and helmet type), showed a clear overall improvement (ranging from 10 percent to 46 percent) in 68 of 72 impact tests. Overall, System 2 improved impact performance by 24.6 percent and System 3 provided a 28.1 percent improvement.



(a)

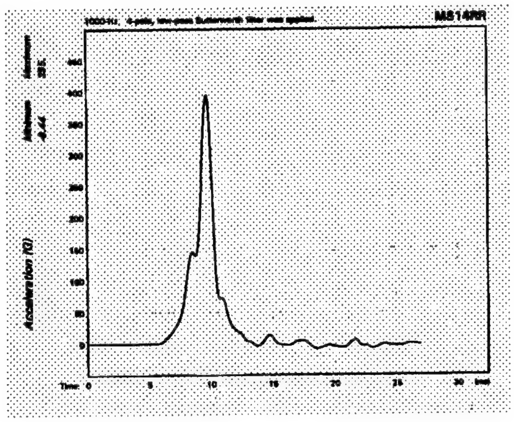


(b)

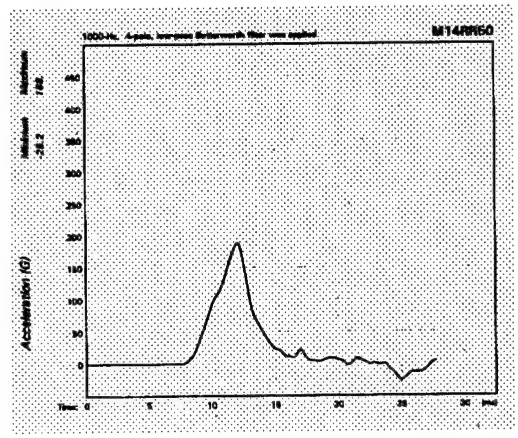


(c)

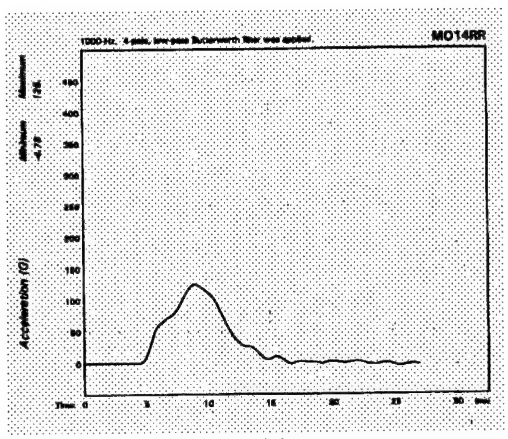
Figure 15. Medium PASGT, frontal impact at 10.0 fps. (a) System 1 helmet (b) System 2 helmet. (c) System 3 helmet.



(a)



(b)



(c)

Figure 16. Medium PASGT, rear impact at 14.14 fps. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.

Table 4.
Size medium helmets, peak headform accelerations during helmet impact, clustered by impact velocity.

Impact velocity (fps)	Impact site	System 1 (Peak G)	System 2 Peak (G)	System 2 Change[1] (G)	System 2 Percent[2] change	System 3 Peak (G)	System 3 Change[1] (G)	System 3 Percent[2] change
10.0	Front	152	121	-31	20%	129	-23	15%
	Rear	80	94	+14	17%	57	-23	29%
	Left nape	114	93	-21	18%	84	-30	26%
	Right nape	103	96	-7	7%	74	-29	28%
	Mean (all)[3]	112	101	-11	10%	86	-26	23%
	Mean (back)[4]	99	94	-5	5%	72	-27	27%
14.14	Front	281	195	-86	31%	253	-28	10%
	Rear	395	188	-207	52%	125	-270	68%
	Left nape	291	192	-99	34%	249	-42	14%
	Right nape	434	264	-170	39%	283	-151	35%
	Mean (all)[3]	350	210	-140	40%	228	-122	35%
	Mean (back)[4]	373	215	158	42%	219	-154	41%
17.32	Front	445	247	-198	44%	268	-177	40%
	Rear	522	290	-232	44%	212	-310	59%
	Left nape	530	508	-22	4%	511	-19	4%
	Right nape	530	444	-86	16%	514	-16	3%
	Mean (all)[3]	507	372	-135	27%	376	-131	26%
	Mean (back)[4]	527	414	-113	21%	412	-115	22%

Notes:
1. Change is the peak G difference from the System 1 helmet. A negative number is an improvement while a positive number is a decrement in performance.
2. Percent change is the calculated percentage change from the System 1 helmet.
3. Mean (all) is the average of the four impact sites (front, rear, left nape, and right nape).
4. Mean (back) is the average of the three rearmost impact sites (rear, left nape, and right nape).

Table 5.
Size large helmets, peak headform accelerations during helmet impact, clustered by impact velocity.

Impact velocity (fps)	Impact site	System 1 (peak G)	System 2 Peak (G)	System 2 Change[1] (G)	System 2 Percent[2] change	System 3 Peak (G)	System 3 Change[1] (G)	System 3 Percent[2] change
10.0	Front	176	165	-11	6%	101	-75	43%
	Rear	134	95	-39	29%	58	-76	57%
	Left nape	116	75	-41	35%	56	-60	52%
	Right nape	74	73	-1	0%	58	-16	22%
	Mean (all)[3]	125	102	-23	18%	68	-57	46%
	Mean (back)[4]	108	81	-27	25%	57	-51	47%
14.14	Front	230	232	+2	0%	244	+14	6%
	Rear	322	161	-161	50%	118	-204	63%
	Left nape	316	151	-165	52%	163	-153	48%
	Right nape	400	224	-176	44%	157	-243	61%
	Mean (all)[3]	317	192	-125	39%	171	-146	46%
	Mean (back)[4]	346	179	-167	48%	146	-200	58%
17.32	Front	331	317	-14	4%	275	-56	17%
	Rear	510	270	-219	43%	250	-260	51%
	Left nape	382	313	-69	18%	507	+125	33%
	Right nape	538	449	-89	16%	408	-130	24%
	Mean (all)[3]	440	337	-103	23%	360	-80	18%
	Mean (back)[4]	477	344	-133	28%	389	-88	18%

Notes: 1. Change is the peak G difference from the System 1 helmet. A negative number is an improvement while a positive number is a decrement in performance.
2. Percent change is the percentage change from the System 1 helmet.
3. Mean (all) is the average of the four impact sites (front, rear, left nape, and right nape).
4. Mean (back) is the average of the three rearmost impact sites (rear, left nape, and right nape).

Helmet dynamic stability

Helmet dynamic stability tests have demonstrated that the CGF Helmets manufactured retention harness provided a 43.5 to 47.0 percent improvement in stability over the current airborne retention system. The three angular displacements of each of the System 1, 2, and 3 helmet stability tests are shown in Figure 17. Depicted in Figure 18 is a comparison of the average displacements between the three helmet configurations. Peak forward and rearward helmet rotation values are summarized in Table 6.

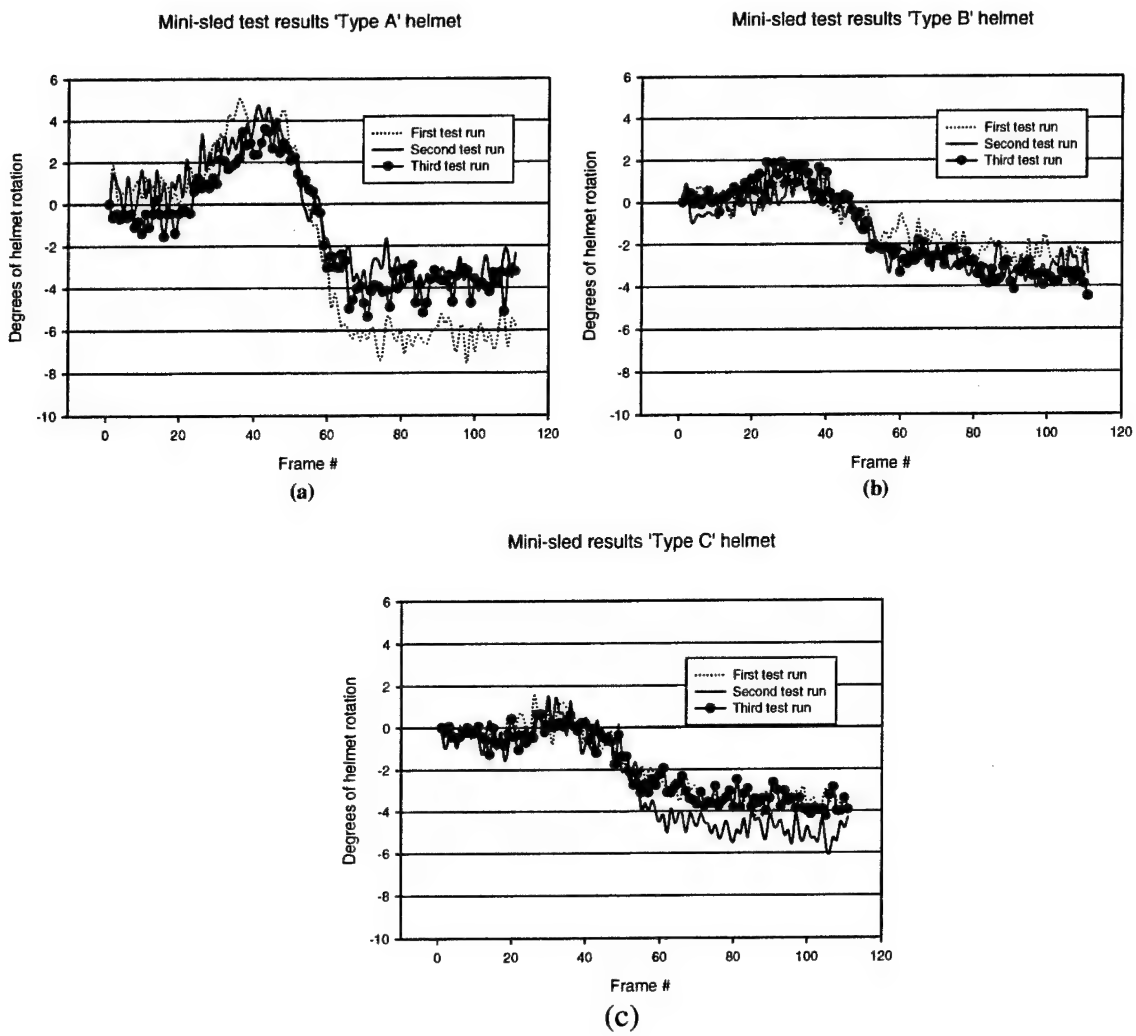


Figure 17. Helmet stability test results. (a) Three trials of System 1 helmet. (b) Three trials of System 2 helmet. (c) Three trials of System 3 helmet.

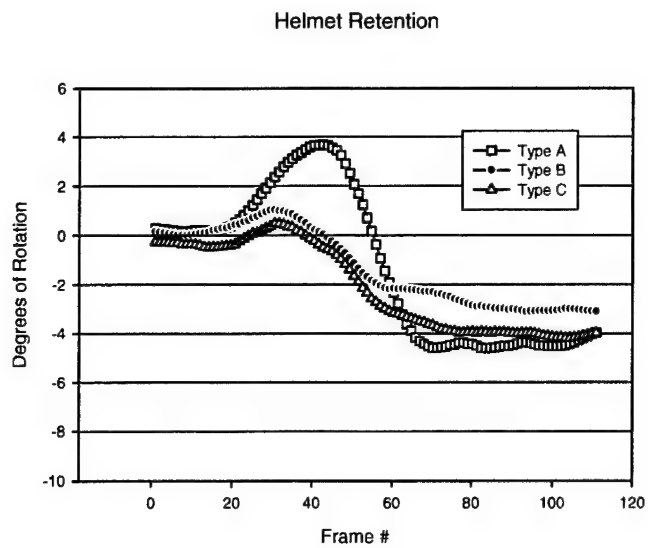


Figure 18. Average helmet rotation of the System 1, 2 and 3 helmet configurations.

Table 6.
Summary results of mini-sled test.

Helmet tested	**Mean upward rotation (Deg.)**	**Mean downward rotation (Deg.)**	**Total # of degrees**	**Percent improvement**
Std Para System 1 configuration	4.00°	5.36°	9.36°	Baseline
CGF Helmets 3 point in System 2 configuration	1.51°	3.45°	4.96°	47.0%
CGF Helmets 3 point in System 3 configuration	0.96°	4.33°	5.29°	43.5%

Note: The mean is based on the performance of three trials per configuration.

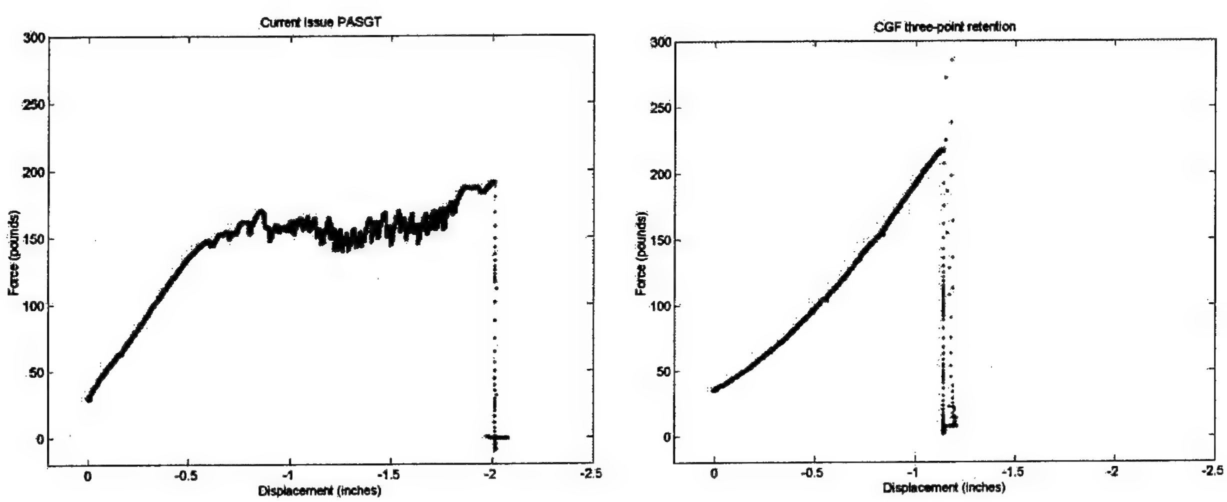
Chinstrap strength and elongation

Chinstrap quasi-static tensile test results are provided in Table 7 and Figure 19. At 195 lbs (867.4 N) tensile force, the System 1 chinstrap adjustment buckle failed. The total elongation of the current issue chinstrap was 2.0 inches (50.8 mm).

The CGF Helmets' YKK brand chinstrap fastener buckle failed at 215 lbs (956.4 N) tensile force. The chinstrap on the CGF Helmets' three-point harness elongated 1.15 inches (29.21 mm). A single test of each configuration was performed due to limited chinstrap assets.

Table 7.
Detail test results of Tinius-Olsen chinstrap pull test.

Helmet retention strap tested	**Max force applied at failure**		Max elongation	
	lbf	**N**	**inches**	**millimeters**
Standard issue nylon strap & pull-the-dot fastener	195	867.4	2.00	50.80
CGF Helmets 3 point harness with YKK buckle in PASGT	215	956.4	1.15	29.21



(a) (b)

Figure 19. Tensile test results of chinstraps installed in large size PASGT. (a) Standard chinstrap. (b) CGF Helmets three-point retention.

In Figure 19(a), at 150 lbs (667.23 N) of force, the bar in the adjustment buckle reached its yield point and began to bend. During this period, the webbing of the chinstrap began to slip. In

Figure 19(b), the strap and buckle fastener handled the increased loading without slipping until the YKK manufactured fastener buckle suffered a catastrophic failure.

Weight

Examination of Table 8 shows that, for the small size PASGT, System 2 was 2.3 percent heavier and System 3 was 4.8 percent heavier than System 1. For the medium size PASGT version, System 2 was 2.5 percent heavier and System 3 was 5.3 percent heavier. For the large size PASGT, System 2 was 5.2 percent heavier, whereas System 3 was 1.6 percent lighter than System 1. Detailed component weights are contained in Appendix D. Note that some components are used in multiple helmet sizes but their use is inconsistent across all experimental helmet configurations. Many components used in Systems 1 and 2 get larger and heavier as the helmet size increases. For example, the suspension systems increase in size as the helmet size increases. In contrast, System 3 uses the same size pads and retention harness in all helmet sizes so the weight difference is attributed to the increased PASGT shell size and sometimes helmet cover size (medium and large PASGT shells use the same size covers).

Table 8.
Weight and mass comparisons of the current issue parachutist helmet configuration (System 1) with System 2 and 3 configurations.

Helmet Configuration	Mass lbs (g)			% Difference	
	System 1	System 2	System 3	System 2	System 3
Small size PASGT	3.37 (1528.6)	3.45 (1566.7)	3.54 (1603.8)	+2.3	+4.8
Medium size PASGT	3.54 (1605.7)	3.63 (1646.6)	3.74 (1696.4)	+2.5	+5.3
Large size PASGT	3.86 (1750.9)	4.07 (1847.2)	3.80 (1722.6)	+5.2	-1.6

Note: % Difference is the difference from the System 1 helmet.

Discussion

Impact attenuation

Seventy-two drop tests were conducted in this phase of the project. Of the 48 possible comparisons between the baseline and two experimental helmet configurations, the experimental configurations performed better in 44 tests (Tables 3 and 4). The four tests in which the baseline helmet's performance was better are discussed below.

Table 4 (medium-size helmets) reveals an increase in headform acceleration with the System 2 helmet over the baseline helmet (System 1) during rear impact at an impact velocity of 10 fps (3.05 m/s). This 14 G increase over the baseline performance of 80 G translates to a 17 percent increase. There are two possible explanations for this result. First, comparison of the 80 G result to the other three impact sites tested on the System 1 helmet shows it to be 23 G lower (better) than the next highest. A comparison of the medium size System 1 helmet results with those of the large size (Table 5) fails to confirm this pattern, suggesting that the 80 G result may be an instance of unusually good performance for the baseline helmet. Second, the Skydex® nape pad used in the System 2 helmet was selected because of its superior performance at higher (and more dangerous) velocities. This is illustrated by the helmet's peak G reduction in the rear impacts at the 14.14 (4.31 m/s) and 17.32 fps (5.28 m/s) impact velocities. In these two tests, the System 2 helmet reduced the peak G by 207 and 232 for the 14.14 fps (4.31 m/s) and 17.32 fps (5.28 m/s) impact velocities respectively. Better protection against more severe impacts must be weighed against the possibility of less protection against milder impacts with this configuration.

Table 4 provides the results for the large-size helmets. For the System 2 helmet, the 14.14 fps (4.31 m/s) frontal impact produced increased headform acceleration over the baseline helmet. This increase was two G, which is negligible (less than one percent). The System 3 helmet also

produced a higher peak G level at this condition [14.14 fps (4.31 m/s), frontal impact]. This increase was 14 G (six percent) over the baseline (230 G). This is attributed to the System 3 helmet having a single trapezoidal pad in the front of the helmet with two identical pads positioned in the rear. The effect of this single forward pad to dual rear pad difference is that the rear pads displace the headform forward in the helmet, causing the forward pad to compress, thereby reducing the available stopping distance. All frontal impact test results were greater than the rear for every impact velocity of the System 3 helmet. However, improving frontal impact performance of this helmet configuration would result in reducing available stopping distance in the rear, where improvement is most needed and Soldiers are most frequently injured. There is also evidence that the baseline helmet peak G value (230 G) may again be an instance of unusually good performance for this test condition (14.14 fps frontal impact). During exploratory testing to evaluate other candidate helmet materials, the baseline helmet was tested in the frontal region on two occasions at 14.14 fps (4.31 m/s). These two exploratory tests provided peak G values of 247 and 271 G, both higher than the System 3 helmet performance of 244 G. Another source of test-to-test variability is that the helmets are fitted onto a metallic headform that lacks a chin, making consistent fit and strap adjustment difficult to achieve.

The System 3 helmet produced a peak acceleration value in excess of baseline at the 17.32 fps (5.28 m/s), left nape test condition. This was a 125 G increase over the baseline helmet (33 percent). However, performance at the right nape location, with the same test conditions, was approximately 100 G lower—an unexpected difference as the helmets are symmetrical and there is no reason to expect a right-left difference. This anomaly is believed to result from test variability, as an artifact of the test machine/software anomaly. Performance variation could result from orienting the test headform, and this particularly heavy helmet can shift as it is being raised for the test.

Helmet dynamic stability

A well-designed retention system should limit the amount of forward and rearward helmet rotational displacement when the head is exposed to acceleration (Hines et al., 1990). Helmet-mounted accessories such as night observation devices (NODs) and communications equipment (microphones, ear buds, etc.) place greater demands on the helmet retention system. If the helmet is rotating excessively, the use of helmet-mounted displays will be much more difficult, if not impossible.

Paschal et al., (1990) fabricated and tested a helmet retention harness that was attached at the forward mounting holes of the PASGT and at the rear most hole in the PASGT. The result of their testing showed that the increased nape strap-to-chinstrap distance resulted in improved helmet stability. The CGF Helmets' manufactured three-point harness uses the same principle as the Paschal et al. prototype.

As evidenced by the results of the dynamic stability test, all components within the suspension/retention system play a role in the stability of the helmet. Even though System 2 and 3 helmet configurations employ the same CGF Helmets' retention harness, System 2 exhibits

greater stability. This may be due to increased friction between the headform and the headband employed in System 2.

Chinstrap strength and elongation

Chinstrap strength and maximum elongation are of importance when evaluating helmet retention systems. One study showed that where helmet losses occurred, a failure of the helmet retention system was a primary factor (Reading et al., 1984). Helmet chinstrap strength plays a significant role in the ability of the helmet to remain on the wearer's head. Obviously, if the chinstrap/retention system suffers a catastrophic failure, the helmet will become dislodged and cannot protect the wearer. Also, if the helmet is not properly oriented it cannot protect the head from impact (Paschal et al. 1990). Excessive elongation of the retention system will exacerbate helmet instability and, depending upon the magnitude, could result in the helmet being dislodged. Helmet instability will worsen if helmet mounted accessories such as night vision goggles (NVGs) and communications are added. The CGF Helmets' three-point retention harness withstood approximately 9.3 percent greater quasi-static tensile force and experienced 42.5 percent less elongation than the current airborne retention harness.

Weight

Weight has always been an important consideration when designing, evaluating or selecting military equipment. This importance is highlighted with the present day military doctrine of being rapidly deployable and highly mobile. Reducing the overall weight a Soldier has to carry is the design goal for Soldier equipment. In this study, weight reduction was a difficult task as the majority of helmet system weight is due to the helmet shell—which could not be modified. To provide improved impact attenuation properties, the addition of material was required and this in turn increased overall weight.

Miscellaneous factors

Preliminary experience with helmets employing energy-attenuating pads like those in Helmet System 3 suggests that increased heat stress may be a factor. This may occur because of increased surface area coverage, reduced ventilation, and/or heat accumulation within the pads. The cloth coverings may also retain debris and become a sanitary issue under field conditions. On the other hand, some claim that heat and moisture is wicked away, thus reducing heat stress.

During testing of the PASGT helmets in various other configurations (reported in Part I), it was noted that during "nape" impacts, the rear steel screw would strike the anvil and result in high headform accelerations. Two rear sites (left nape and right nape) were selected because they challenge the impact protective materials, and the nape area is a potential impact site with poor parachutist landing technique. Also, there is the risk of severe scalp laceration from the edge of the traditional A-nut. To reduce the possibility of scalp laceration, the System 2 and 3 helmets were configured with the T-nut and locking screw originally used to secure the current issue chinstrap.

Currently, military performance specifications for blunt impact attenuation for the airborne Soldier's helmet do not exist. The test methods employed during this series of tests were compiled from commercial helmet test standards and military aviation helmet test standards modified to take into account the unique requirements of the airborne Soldier.

Conclusions

Both candidate systems described in this report provided improved overall performance in impact attenuation, dynamic stability and chinstrap strength, compared to the current U.S. Army airborne helmet configuration (System 1). Despite the four isolated tests in which baseline configurations appeared to perform better, impact performance (averaged for impact velocity and helmet type) showed a clear improvement overall (ranging from 10% to 46%). Performance is also improved in helmet Systems 2 and 3 when collapsing across impact location or size. Overall, the configuration of System 2 improves impact performance by 24.6% and the configuration of System 3 improves by 28.1%. The candidate systems are slightly heavier than System 1, but the improved impact performance is believed to represent a considerable overall benefit. The seven systems that were unsuccessful are reported in Part I of this report (Trumble, McEntire, Crowley, 2004).

Recommendations

Helmet Systems 2 and 3 should be evaluated under field conditions to assess human factors performance, as well as their effectiveness in reducing head injury rates in the airborne community.

Blunt injury performance standards for paratrooper helmets (as well as other combat helmets) should be developed. There is precedent for blunt impact attenuation requirements in an acquisition program—the Modular Integrated Communications Helmet (MICH) (Appendix C). In addition, better studies should be conducted to determine the actual impact velocity occurring during head-to-ground contact in airborne operations.

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Appendix A.

Commerce Business Daily announcement (USAARL).

[Commerce Business Daily: Posted in CBDNet on May 8, 2001]
[Printed Issue Date: May 10, 2001]
From the Commerce Business Daily Online via GPO Access
[cbdnet.access.gpo.gov]

PART: U.S. GOVERNMENT PROCUREMENTS
SUBPART: SERVICES
CLASSCOD: A--Research and Development--Potential Sources Sought
OFFADD: Director, USAMRAA, 820 Chandler St, Fort Detrick, MD
21702-5014
SUBJECT: A--SOURCES SOUGHT FOR ALTERNATIVE INFANTRY HELMET SUSPENSION
AND RETENTION SYSTEM
DUE 060401
POC Patricia K. Nelson, Contracting Officer, 301-619-2702, e-mail:
patricia.nelson@amedd.army.mil
DESC: ALTERNATIVE INFANTRY HELMET SUSPENSION AND RETENTION SYSTEMS:

This is a market survey to support the U.S. Army Aeromedical Research Laboratory (USAARL) review of helmet fitting and retention systems that are compatible with the standard U.S. Army infantry ballistic helmet known as the Personnel Armor System Ground Troops (PASGT) helmet. Specifically, USAARL is seeking commercial off the shelf (COTS) and non-developmental item (NDI) alternatives to replace the helmet's current web (sometimes called "cradle") suspension assembly, headband, chinstrap, parachutist pad (rear), and parachutist retention strap. Conceptual and developmental designs are welcomed for submission. Candidate materials must be fully compatible with the existing helmet shell and hole pattern and must not require the use of additional shell sizes. Submitted material configurations that require helmet shell modification will not receive consideration for follow-on procurement. Items that are fully compatible may be considered for purchase in small quantities (10 to 20 units) for laboratory assessment. These laboratory assessments will include blunt impact protection, chin strap strength, and dynamic retention/stability. Comparative laboratory performance assessments will be made against the standard PASGT helmet in the parachutist's airborne configuration (parachutists impact liner and retention strap). Additional consideration factors include ease of retrofit and use, cleanliness and sanitation, user comfort and heat retention, durability, and cost. The laboratory data and consideration of these other factors will be used to down select to one or two configurations for inclusion in a field study being conducted by the USAARL. To support this field study, approximately 500 units of the selected item may be procured. Samples and 3-D models are encouraged. Proprietary information MUST be marked as such, on a page-by-page basis. This Request For Information (RFI) does not, in any way constitutes a Request For

Proposal (RFP) and as such, is not to be construed as a commitment by the Government. The Government does not intend to award a contract on the basis of this notice, nor otherwise pay for information / items solicited. Data, samples, and 3-D models will not be returned. To be of maximum benefit to the program, responses must be received by 1 June 2001. Interested sources should electronically submit literature/brochures describing their concepts using either MS Word, MS Excel, MS PowerPoint, or Adobe Acrobat compatible formats to Joe McEntire, email address joe.mcentire@se.amedd.army.mil NLT 30 days after the posted date. POC for this action is Joe McEntire, Principal Investigator, telephone number (334) 255-6896. This is a market survey requesting information only. No solicitation will be issued against this notice. If a formal solicitation is generated at a later date, a solicitation notice will be published. All information is to be submitted at no cost or obligation to the Government. The Government reserves the right to reject, in whole or in part, any private sector input as a result of this market survey. Telephone requests are not acceptable.
EMAILADD: joe.mcentire@se.amedd.army.mil
EMAILDESC: patricia.nelson@amedd.army.mil
CITE: (W-128 SN50L571)

Note: The above CBD announcement has been reformatted to better comply with USAARL report guidelines, the content has not been altered.

Appendix B.

Manufacturers list.

CGF Helmets Inc. (MSA Gallet)
30 Industrial Drive, Suite 10
Newport, VT 05855
Phone: (802) 334-2774
Fax: (802) 334-2963
Email: cgfbowen@sover.net

Cramer Controls
99 Thompson Road
Avon, CT 06001-3000
Phone: (860) 673-6079
Fax: (860) 404-0408

Gentex Corporation
PO Box 315
Carbondale, PA 18407
Phone: (570) 282-3550
Fax: (570) 282-8555

Kistler Instruments AAAG
Winterthur, Switzerland

Lucas Schaevitz™ Sensors
1000 Lucas Way
Hampton VA 23666
Phone: (757) 766-1500
Fax: (757) 766-4297

Metraplex Corporation
Formerly of Ridgefield CT
Now known as: Herley-Metraplex
10 Industry Drive,
Lancaster PA 17603
Phone: 717-397-2777
Fax: 717-397-7079
email: mpxmrktg@herley.com

Oregon Aero, Inc.
34020 Skyway Drive
Scappoose, OR 97056
Phone: (503) 543- 7399
Fax: (503) 543-7199

Panasonic
Division of Matsushita Electric Corporation of America
One Panasonic Way (3F-5)
Secaucus, NJ 07094
Phone: (800) 524-0864

Photographic Analysis Ltd
210 Don Park Road Unit 12
Markham Ontario L3R2V2 CANADA

RBR Armor Inc.
10455 Dow-Gil Road
Ashland VA 23005
Phone: (800) 672-7667
Fax: (804) 798-7125

Sartorius Corporation
131 Heartland Blvd
Edgewood, NY 11717

Skydex® Cushioning Technologies
Sales & Marketing
258 Harvard Street PMB 313
Brookline, MA 02446
Phone: (617) 232-4617
Fax: (617) 232-9608
Email: betsy@skydex.com
www.skydex.com

Snell Memorial Foundation Inc.
3628 Madison Avenue, Suite 11
North Highlands, California 95660
Phone: (916) 331-5073
Fax: (916) 331-0359
Email: info@smf.org
http://www.smf.org

Spin Physics 2000, Kodak
3099 Science Park Road
San Diego, CA 92121-1011

T-Hydronics Inc
Ohio
Phone: (614) 965-9340

Testing Machine Co.
Tinius-Olsen
Willow Grove, PA

U.S. Department of Justice
Unicor, Federal Prison Industries, Inc. (PASGT helmet shells)
320 First Street, N.W.
Washington, D.C. 20534
Phone: (202) 272-6314

YKK (USA) Inc.
Atlanta, GA
Phone: (770) 427-5521
Fax: (770) 421-8150
http://ykkfastening.com/
email: info@ykk.com

Appendix C

Commerce Business Daily announcement (USSOCOM).

[Commerce Business Daily: Posted in CBDNet on April 30, 1999]
[Printed Issue Date: May 5, 1999]
From the Commerce Business Daily Online via GPO Access
[cbdnet.access.gpo.gov]

PART: U.S. GOVERNMENT PROCUREMENTS
SUBPART: SUPPLIES, EQUIPMENT AND MATERIAL
CLASSCOD: 84--Clothing, Individual Equipment and Insignia
OFFADD: United States Special Operations Command, Directorate
of Procurement (SOAC-KB), 2418 Florida Keys Ave., MacDill AFB,
FL 33621-5316
SUBJECT: 84--MODULAR INTEGRATED COMMUNICATIONS HELMET (MICH)
SOL USZA22-99-R-0018
DUE 060199
POC Ms. Valerie Romanchek, Contract Specialist, (813)840-5461
DESC: The United States Special Operations Command has a requirement for commercial off-the-shelf ballistic helmets, associated spare parts kits and use and care manuals. The helmet shall consistently provide fragmentation and ballistic in a balanced and stable configuration. As a threshold, the helmet shall provide fragmentation protection (V50) equal to the Personal Armor Systems for Ground Troops (PASGT) helmet (2 grain RCC @ 4075 fps, 4 gr RCC @ 3450 fps, 16 gr RCC @ 2425 fps, 64 grain RCC @1700 fps and 17 gr FSP @ 2150 fps) with an objective requirement of the same protection at a reduced weight. As a threshold, the helmet shall provide handgun protection (V zero) against a 124 grain, 9mm @ 1400 fps (+50 fps) with minimal backface deformation with an objective requirement of the same protection at reduced weight. As a threshold, the helmet shall provide impact protection of 150g's max @ 10 fps impact velocity with an objective of increased protection with reduced weight, bulk and heat stress. Fragmentation testing shall be in accordance with MIL-STD-662F. Handgun testing shall be in accordance with NIJ Standard 0106.01 except that five (5) shots will be taken as follows: four (4) side shots IAW the standard except that one side shot (back preferred) shall be to a fastener (bolt, screw, etc.) at 0 zero obliquity and one (1) shot at 0 zero obliquity to the crown. Impact protection shall be tested in accordance with ANSI Z90.1 except that the drop height shall be increased to account for friction resistance in order to achieve the desired impact velocity. The complete helmet shall weigh no more than 3.25 lbs for the largest size without mounts and ancillary equipment (threshold), with the objective requirement being the same level of protection at a 20% weight reduction. The helmet shall be compatible with and possess the capability to mount night vision devices, and be compatible with parachutist's free fall oxygen masks. The helmet shall consistently perform in all environmental conditions from -40 degrees F to +160 degrees F. The helmet shall be capable of withstanding and consistently performing (no performance or physical degradation) in a maritime environment. The helmet shall be able

to withstand 750 hours (threshold) of continuous maritime exposure with an objective of 1200 hours. The helmet shall consistently perform after a three foot immersion in salt water for three hours (threshold) with the objective of withstanding immersion at 66 feet in salt water for twelve hours. This request for proposal (RFP) represents a two-phased approach as part of a significant modernization effort for the joint Special Operations Forces called SPEAR (Special Operations Forces Personal Equipment Advanced Requirements). Phase I is for helmet systems which will undergo developmental testing/operational testing (DT/OT) and Phase II is for production. The Government invites commercial suppliers to participate in this innovative acquisition effort. The United States Special Operations Command (USSOCOM) intends to issue a draft RFP on the USSOCOM Home Page at http://soal.socom.mil o/a 6 May 99 with the final RFP release o/a 10 May 99 in accordance with FAR, Subpart 12.6. The standard industrial classification is 3842 and the small business size standard is 500 employees. The Department of Defense requires all contractors to be registered in the Central Contractor Registration (CCR) no later than May 31, 1998, to receive solicitations, contract awards or payments. Actual samples, which directly correspond and reflect the technical proposal and data submitted for each size proposed shall be required to be delivered simultaneously with offeror's proposals. Over and above the actual samples submitted, the Government may desire to order approximately ten (10) each of the proposed helmets to assist with the source selection evaluation. The Government reserves the right to make multiple awards for Phase I of this RFP. The successful offeror(s) will deliver up to 100 helmets, associated spare part kits and use and care manuals, which will undergo DT/OT. Based upon results of the DT/OT, the Government will make a best value downselect decision and exercise the production option to only one contractor. Phase II, the production phase of the contract will have one five year ordering period with a contract ceiling of up to 20,000 ballistic helmet systems for joint SOF fielding including associated spare parts kits, replacement spares and use and care manuals. This solicitation will be an unrestricted competitive procurement. All responsible sources may submit a proposal, which shall be considered by the agency. No further notification will be provided and written solicitations will not be mailed or faxed. The RFP documents shall be downloaded individually by interested offerors. It is the offeror's responsibility to monitor this site for release of the draft and final solicitation and any subsequent amendments to the solicitation.
LINKURL: http://soal.socom.mil
LINKDESC: Click here to go the USSOCOM Home Page
EMAILADD: romancv@socom.mil
EMAILDESC: keelers@socom.mil
CITE: (W-120 SN326587)

Note: The above CBD announcement has been reformatted to better comply with USAARL report guidelines, the content has not been altered.

Appendix D

Weight and mass comparisons* of the current issue parachutist helmet configuration (System 1 configuration) with System 2 and System 3 configurations.

Table D-1.

Helmet Configuration	Weight (lbs)			Mass (g)		
	System 1	System 2 (% difference)	System 3 (% difference)	System 1	System 2	System 3
Small size PASGT	3.37	3.45 (+2.3)	3.54 (+4.8)	1528.6	1566.7	1603.8
Medium size PASGT	3.54	3.63 (+2.5)	3.74 (+5.3)	1605.7	1646.6	1696.4
Large size PASGT	3.86	4.07 (+5.2)	3.80 (-1.6)	1750.9	1847.2	1722.6

* Actual weights measured at USAARL

Table D-2.
Weights of individual components.

System 1 Configuration	Mass (g)	Wt (oz)	System 2 Configuration	Mass (g)	Wt (oz)	System 3 Configuration	Mass (g)	Wt (oz)
S/M/L Headband	56.7	2.0	S/M/L Headband	56.7	2.0	#7 oval pad	15	0.53
Medium Suspension	46.5	1.64	Medium Suspension	46.5	1.64	#7 trapezoidal pad	23.5	0.83
Para retention strap	9.7	0.34	Skydex® nape pad	57.1	2.01	#6 crown pad	39.5	1.39
Chinstrap assembly	34.3	1.21	CGF Helmets harness	63.1	2.23	CGF Helmets harness	63.1	2.23
T-nut	1.0	0.035	T-nut	1.0	0.035	T-nut	1.0	0.035
Locking screw	2.1	0.074	Locking screw	2.1	0.074	Locking screw	2.1	0.074
A-nut	2.2	0.078	A-nut	2.2	0.078	S camo cover	58.4	2.06
7/16 screw for A-nut	1.8	0.06	7/16 screw for A-nut	1.8	0.06	M/L camo cover	62.4	2.2
Washer. (chinstrap)	0.1	0.0035	Pil front & crown pad	19.0	0.67			
Issue nape pad	34.0	1.2	Comfort donut pad	4.4	0.16			
Retention strap screw	1.9	0.067	S camo cover	58.4	2.06			
Comfort donut pad	4.4	0.16	M/L camo cover	62.4	2.2			
S camo cover	58.4	2.06						
M/L camo cover	62.4	2.2						

Number of components required for each configuration

System 1 helmet:
1 - PASGT shell
1 - Suspension
1 - headband
6 - A-nuts
5 - screws for A-nuts
1 - retention strap screw
1 - chinstrap assembly
2 - chinstrap locking screws and washers
2 - T-nuts
1 - parachutist retention strap
1 - nape pad
1 - helmet cover
1 - comfort donut pad

System 2 helmet:
1 - PASGT shell
1 - Suspension
1 - headband
3 - Locking screws
3 - T-nuts
3 - A-nuts
3 - Screws for A-nuts
1 - CGF Helmets three-point retention harness
1 - helmet cover
1 - Skydex® nape pad

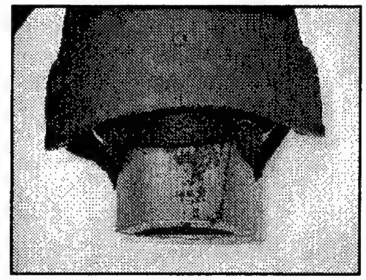
System 3 helmet:
1 - PASGT shell
5 - #7 size Oregon Aero oval pads
3 - #7 size Oregon Aero trapezoidal pads
1 - #6 size Oregon Aero circular crown pad
1 - CGF Helmets three-point retention harness
3 - Locking screws
3 - T-nuts
1 - modified helmet cover
1 - quantity of self-adhesive hook material for inside helmet shell

Appendix E.

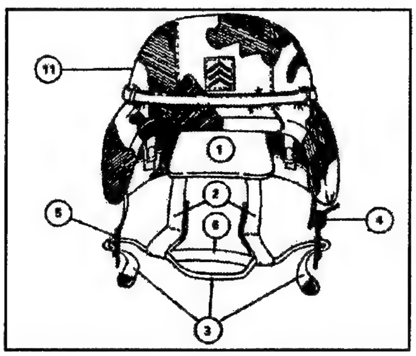
PASGT configured in current parachutist configuration (System 1 configuration).

(a)

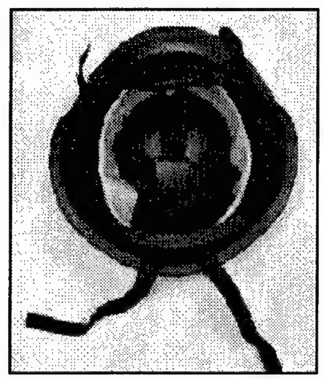
(b)



(c)



(d)



(e)

1 - Nape pad
2 - Retention strap
3 - Chinstrap
4 - Pull-the-dot snap fastener
5 - Adjustment buckle
6 - Chincup portion of chinstrap
11 - Camouflage helmet cover

Figure. PASGT configured in current parachutist configuration (System 1 configuration). (a) Front view. (b) Side view. (c) Rear view. (d) Drawing showing components. (e) Inside view System 1 configuration.

Appendix F.

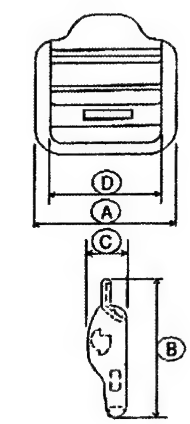
YKK (USA) product data sheets.

ITEM LKE ¾"

DATE 01/2000

YKK(USA)INC. MACON
PRODUCT DATA SHEET

BUCKLE & NOTIONS



STRENGTH

	AVG LB	AVG KG
BREAK STRENGTH	199.2	90.5
SLIPPAGE (at break)	< 1"	
RELEASE FORCE		

DIMENSIONS

	MM	INCH
A	24.30	0.96
B	34.10	1.35
C	8.65	0.34
D	18.90	0.75
E	0.00	0.00
F	0.00	0.00
G	0.00	0.00

MATERIAL & CONSTRUCTION

DELRIN
PLASTIC INJECTION

PROPERTIES

COLOR FASTENERS	WASH	AATCC - 5
	DRYCLEAN	AATCC - 5
	WEATHERING 100 Hr	AATCC - 4 - 5
MELTING POINT (° F)		347 ° F
CHEMICAL RESISTANCE	SOLVENTS	Excellent resistance to a wide variety
	ACIDS/ALKALI	Not recommended outside the pH range of 4 ~ 9
IMPACT (NOTCHED IZOD)	-40 (° F)	1.2 FT LB/IN
	73 (° F)	1.4 FT LB/IN
FLAMMABILITY (FMVSS 302)		AVG 1.9 INCH/MIN
U.L. APPROVAL FOR PFD		NO

496,0100

NOTICE - DISCLAIMER
ANY INFORMATION CONTAINED HEREIN IS FOR THE SOLE PURPOSE OF PROVIDING PURCHASER WITH GENERAL KNOWLEDGE ABOUT YKK PRODUCTS, YKK DOES NOT MAKE ANY WARRANTY OF ANY KIND, NEITHER EXPRESS OR IMPLIED, AS TO THE PRODUCTS, PRODUCT PRICES OR OTHERWISE.

Figure F-1. YKK (USA) product data sheet for adjustment buckle.

ITEM LBRU 3/4"

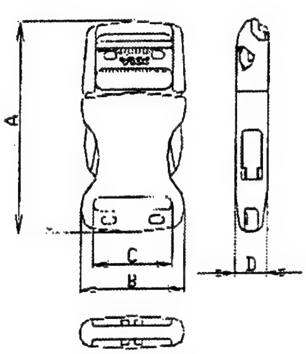
DATE 01/2000

YKK

YKK(USA)INC. MACON

PRODUCT DATA SHEET

BUCKLE & NOTIONS



STRENGTH

		AVG KG	AVG LB
BREAKING STRENGTH	70° F	86.20	190
	-22° F	86.20	190
	160° F		
SLIPPAGE (at 150 lb)		< 1"	
ACCELERATED WEATHERING ASTM G23-89	100 Hr	85.24	
	300 Hr.		
CHEMICAL EXPOSURE:			
• Perchloroethylen	70 Hr.		190
• Deisel Fuel	70 Hr.		190
• Detergent	70 Hr.		190
• Oil	70 Hr.		190

DIMENSIONS

	MM	INCH
A	53.8	2.11
B	26.00	1.02
C	19.30	0.76
D	8.60	0.34

MATERIAL & CONSTRUCTION

DELRIN
PLASTIC INJECTION

PROPERTIES

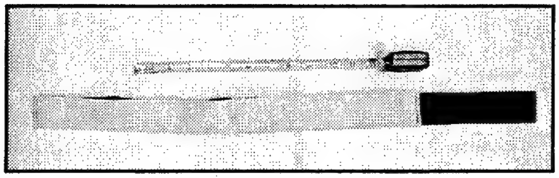
COLOR FASTENERS	WASH	AATCC - 5
	DRYCLEAN	AATCC - 5
	WEATHERING 100 H	AATCC - 4 - 5
MELTING POINT (° F)		347 ° F
CHEMICAL RESISTANCE	SOLVENTS	Excellent resistance to a wide variety of solvents
	ACIDS/ALKALI	Not recommended outside the pH range of 4 ~ 9
IMPACT (NOTCHED IZOD)	-40 (° F)	1.2 FT LB/IN
	73 (° F)	1.4 FT LB/IN
FLAMMABILITY (FMVSS 302)		AVG 1.9 INCH/MIN
MATERIAL FATIGUE	5000 Cycles - UL 1191	Opening & Closing test no failure.
U.L. APPROVAL FOR PFD		YES Use Code 2, 3, 5R

1096.0100

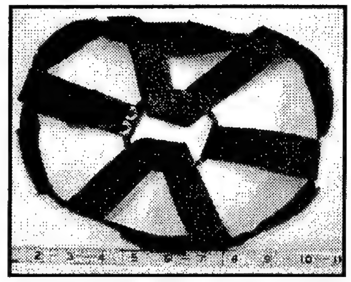
Figure F-2. YKK (USA) product data sheet for fastening buckle.

Appendix G.

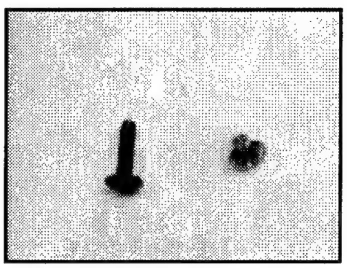
Installation instructions for the System 2 helmet configuration .



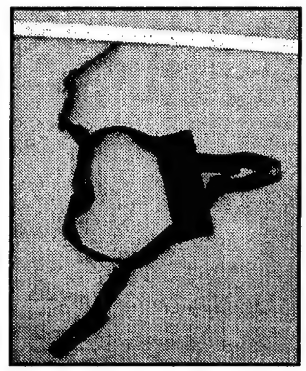
Issue headband



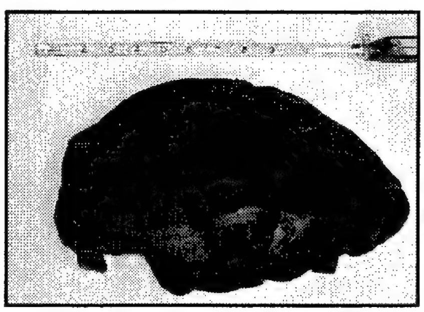
Issue suspension



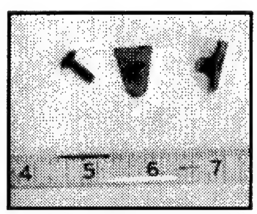
Screw and T-nut



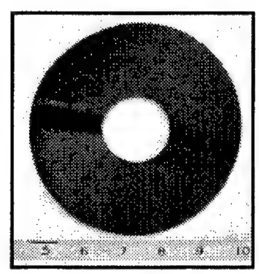
CGF Helmets 3-point harness



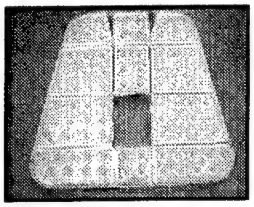
Camouflage cover



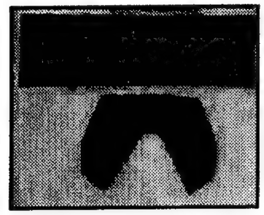
Screw and A-nuts



Comfort donut pad



Skydex® nape pad (black or gray color)



Issue PIL, impact liner parachutist

Installation Instructions for the System 2 Helmet Configuration

Following the measuring of the candidate's head to determine the proper size helmet and components and issuing the appropriate size components to them, the following installation instructions are to be followed:

Step 1. Ensure all six black hook and loop fasteners are unfastened. Fit the headband (Figure 1) to the head of the wearer with the leather portion of the headband being against the head (Figure 2). When the headband is snug around the head, secure it with hook and loop material at the rear.

Figure 1a. Headband suspension side view.

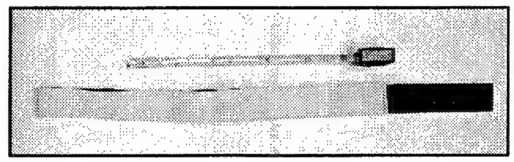


Figure 1b. Headband head side view.

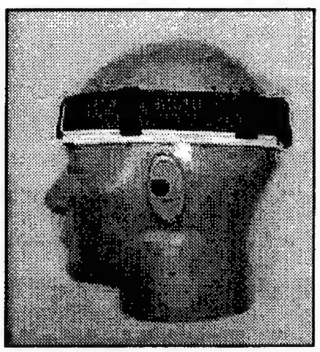


Figure 2. Headband fit to head.

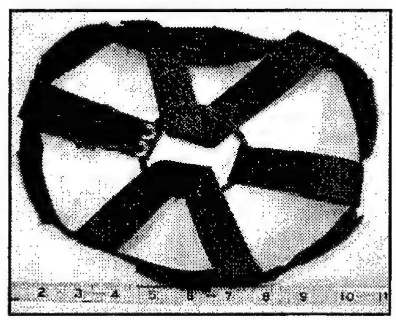


Figure 3. Suspension viewed from helmet side.

Step 2. While keeping the headband fastened, remove it from the head. Ensure all six black hook and loop fasteners are unfastened. The suspension is situated so it is viewed as if it was in the PASGT shell. The drawstring adjustment tab of the suspension is located at the rear (Figure 3). Place the headband in the suspension with the folded edge of the leather facing you and the overlapped hook and loop attachment point of the headband, at the rear of the suspension (Figure 4). Attach the headband to the suspension by attaching it via the straps with hook material to the inside surface of the headband where the loop material is located. Ensure the hook fasteners are around the web strap of the suspension and not caught between the web strap and the headband. After placing the suspension and headband on the head, adjust the suspension to fit the head by pulling the tab on the top of the suspension webbing that has the hook and loop fastener material until the suspension is snug on the head, then attach the tab with hook material to the loop material on suspension webbing (Figure 5).

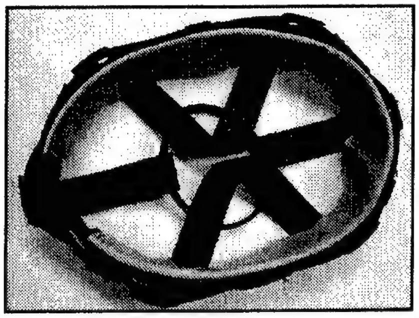


Figure 4. Headband to suspension assembly.

Figure 5. Suspension fit to head.

Step 3. Install the suspension into the inside surface of the PASGT helmet (Figure 6). A total of three A-nuts and 7/16" long slotted, round head screws will be required (Figure 7). Install the suspension at the forward most hole in the PASGT helmet shell. Ensure the A-nut is placed with the flat edge of the A-nut towards the top of the helmet. After passing the threaded shaft of the A-nut through the suspension and then through the PASGT shell, thread the 7/16" screw from the outside surface of the helmet shell into the threaded shaft of the A-nut (Figure 8).

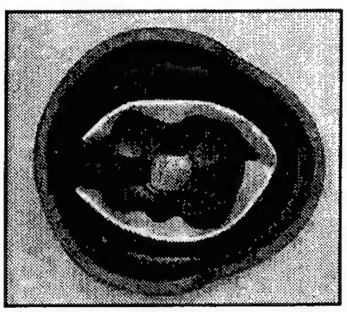


Figure 6. Position of suspension in PASGT.

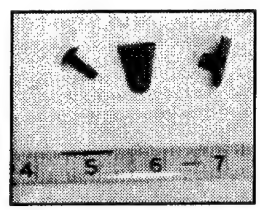


Figure 7. 7/16" Screw and A-nut.

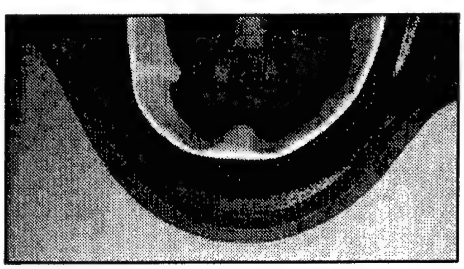


Figure 8. Attaching suspension at front.

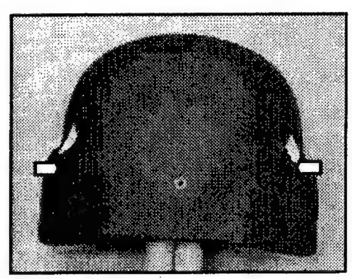


Figure 9. Rearward side points (white arrows).

Two A-nuts and 5/8" screws will then be used in the same fashion to attach the suspension at the rearward sides of the PASGT helmet (Figure 9).

At the wearer's forward sides of the PASGT helmet (Figure 10), two T-nuts and 5/8" locking screws (Figure 11) will be used in the same fashion with the exception that the shaft of the T-nut will be passed through a hole in the retention system (webbing hanger has two holes with grommets, select the upper one for L/XL PASGT, the lower one for XS/S/M PASGT) then through the suspension prior to being passed through the inside of the helmet shell (Figure 12). The retention system adjustment straps should be away from the wearer's face when attached properly. The 5/8" long slotted round head locking screw is inserted from the outside of the PASGT and then threaded into the T-nut.

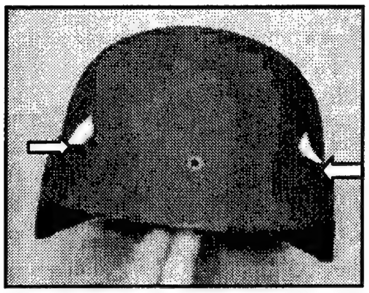


Figure 10. Forward side points (white arrows).

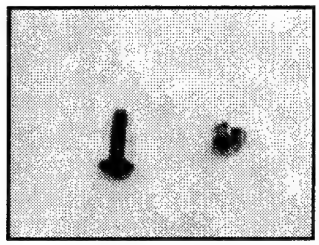


Figure 11. Locking screw & T-nut.

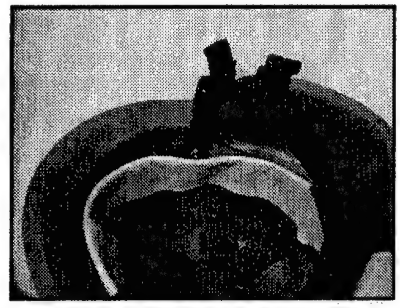


Figure 12. Forward side attachment.

The rear most hole in the helmet shell is used to affix the rear most hole of the suspension system, rear tab of the retention system, and the Skydex® nape pad (Figure 13). The threaded shaft of a T-nut is passed through the rear tab of the retention system (adjustment straps should be away from the wearer's head); following this, the rear most hole in the suspension from the inside surface; then the shaft is passed through the hole in the Skydex® nape pad (the pad being oriented with the narrow portion at the wearer's top of the inside surface of the helmet); and finally, the shaft is placed in the rear most hole of the PASGT helmet shell. The 5/8" locking screw is then placed into the rear hole of the helmet from the outside surface and threaded into the shaft of the T-nut (Figure 14).

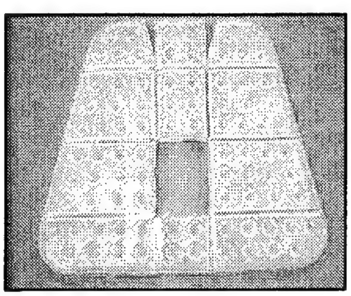


Figure 13. Skydex® Nape Pad (Black or gray color).

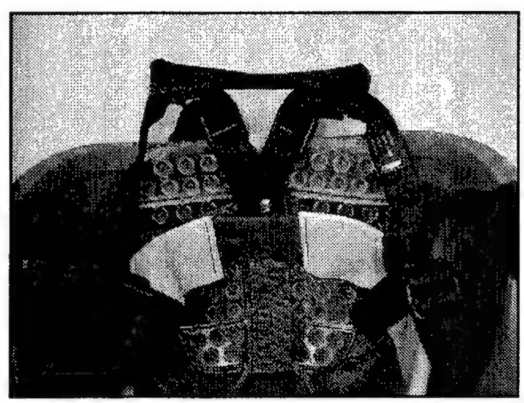


Figure 14. Installation of retention strap and nape pad.

Step 4. Install the PIL (Figures 15 and 16). The liner is trimmed as per the perforations on the PIL for the appropriate size PASGT (Large and XL do not require trimming). The rectangular shaped portion of the PIL is installed between the suspension webbing and the helmet shell (Figure 16c). At the front of the PASGT, the PIL is installed between the suspension webbing and the PASGT shell with the flat edge towards the crown of the helmet (Figure 16d).

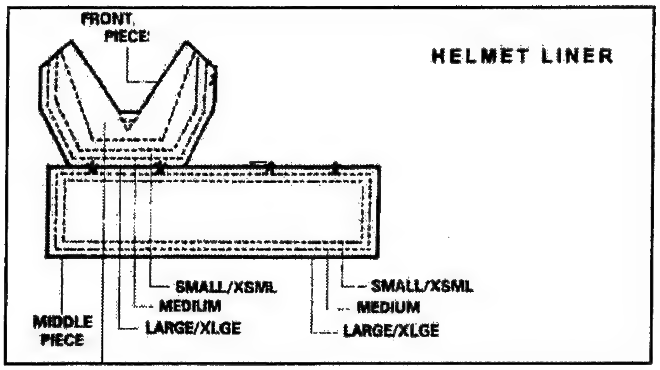


Figure 15. PIL.

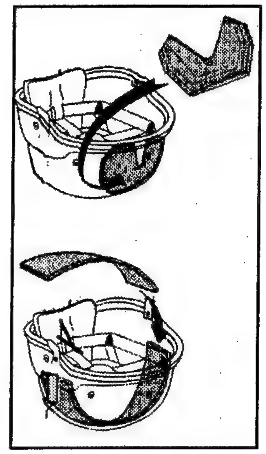


Figure 16a. PIL Liner installation.

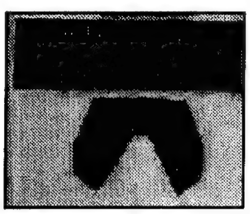


Figure 16b. PIL layout.

Figure 16c. Rectangular portion of PIL in crown area.

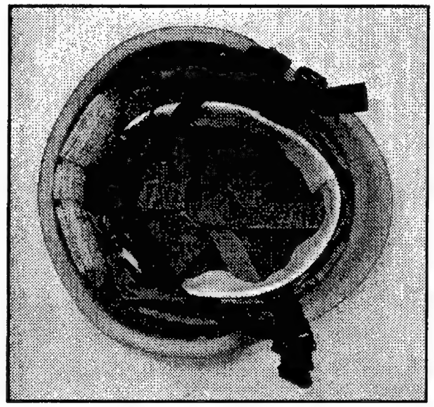


Figure 16d. PIL installation completed.

Step 5. Place the comfort pad donut (Figure 17) on the inside of the suspension and attach to the suspension using the hook and loop material attached to the helmet side of the comfort pad donut (Figure 18).

(a). (b).

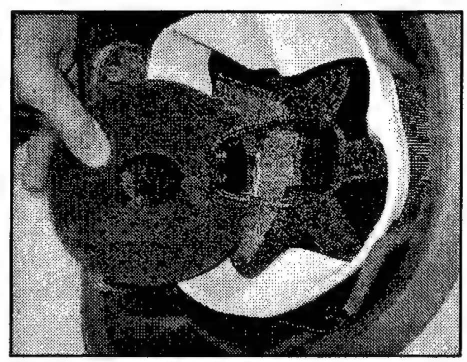


Figure 18. Installation of Comfort pad donut

Figure 17. Comfort pad donut.
(a) Head side, and (b) Helmet side.

Step 6. The camouflage helmet cover (Figure 19) is placed on the helmet shell with the two slotted holes in the edge of the cover at the rear of the PASGT shell. Two additional slotted holes in the edge of the cover will be located (one on either side) at the sides of the PASGT shell (Figure 20). Attach the camouflage cover by looping the straps that are attached to the cover around the suspension at the same portion of the suspension that the headband retention straps are looped around. Affix using the attached hook material on the straps to the corresponding loop material on the cover (Figure 21).

Figure 19. Camouflage helmet cover

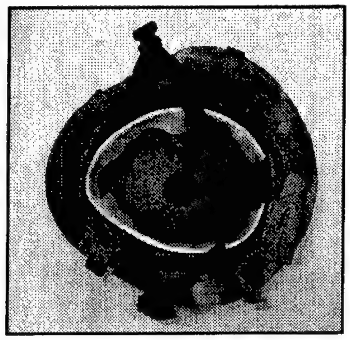


Figure 20. Cover layout.

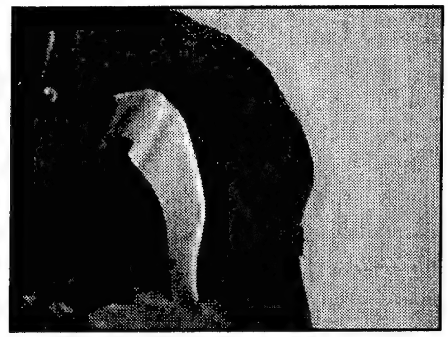


Figure 21. Attaching camouflage cover

At the rear of the camouflage cover, the straps of the harness will have to be unbuckled and passed through the appropriate slot in the rear of the helmet cover and then be refastened (Figure 22). Ensure that the strap is not twisted.

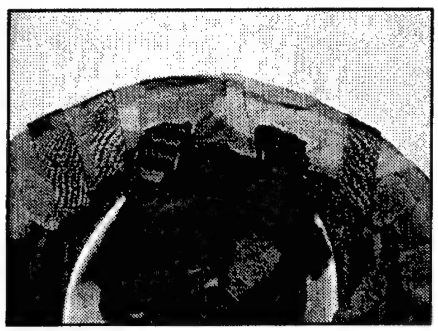


Figure 22. Straps through rear slots in helmet cover.

Step 7. Place the assembled helmet on the head, pass the chinstrap with the quick release buckle around the chin and insert in open end of buckle attached to the left side retention strap (Figure 23a). Grasp the free ends of the retention straps at the front and rear of both sides of the helmet and pull downward on the straps until helmet is comfortable and snug on head (Figure 23b). The rear nape pad is positioned under the rear adjustment buckles (Figure 24). If the helmet sits too high on the head, adjust the drawstring adjustment tab on the suspension by moving it toward the crown (top) of the helmet. If the helmet sits too low on the head, adjust the drawstring adjustment tab on the suspension by moving it toward the rear rim of the helmet.

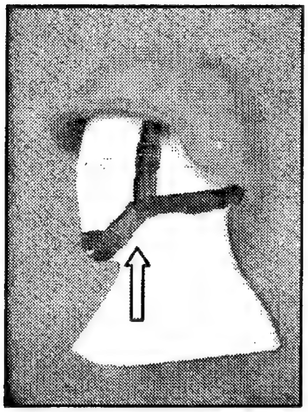


Figure 23a. Quick release buckle.

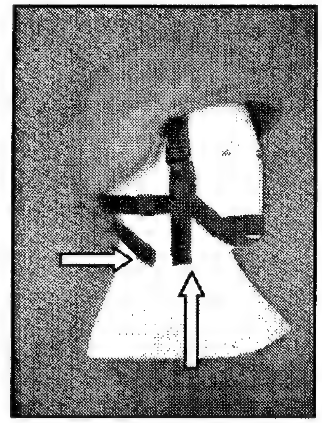


Figure 23b. Adjusting retention straps.

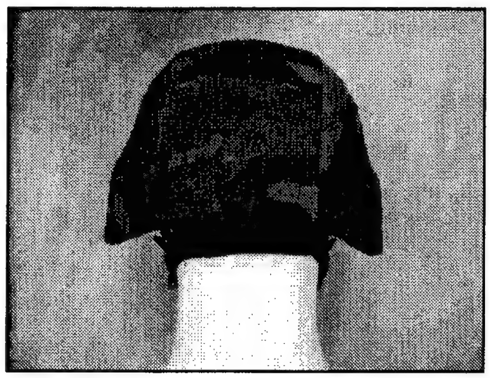
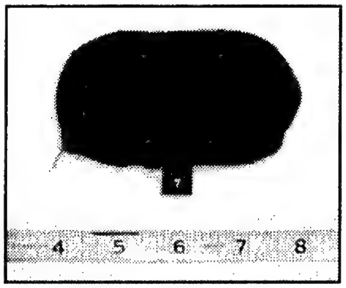


Figure 24. Rear view of nape pad under adjustment buckles.

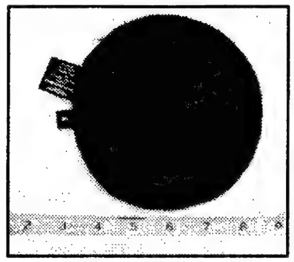
Appendix H.

Installation instructions for System 3 helmet configuration.

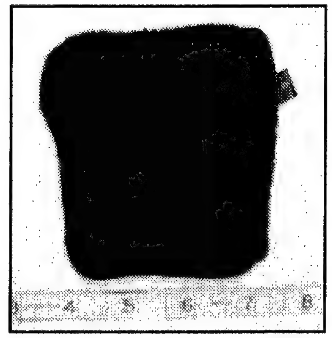
System 3 configuration components



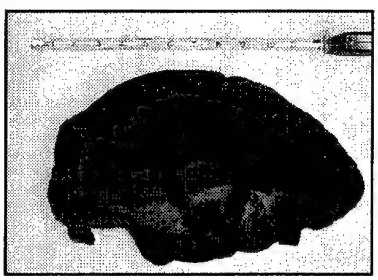
Oval pad (five req'd)



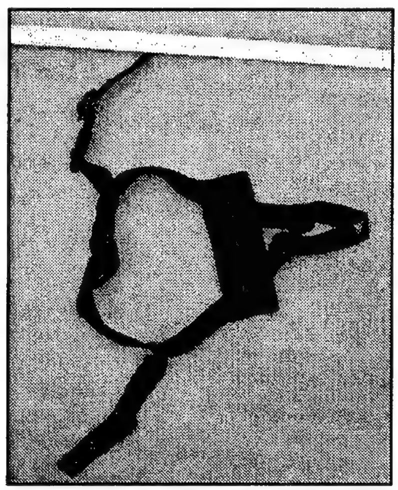
Crown pad (1 req'd)



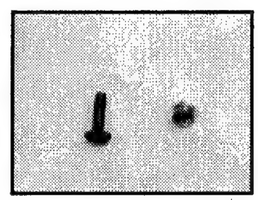
Trapezoidal pad (3 req'd)



Camouflage cover (1 req'd)



3-point harness (1 req'd)



Screw & T-nut
(3 of ea req'd)

Installation Instructions for the System 3 Helmet Configuration

Following the measuring of the candidate's head to determine the proper size helmet and components and issuing the appropriate size components to them, the following installation instructions are to be followed:

Step 1. Install Velcro™ strips or disks to the inner aspect of the PASGT as shown in Figure 1.

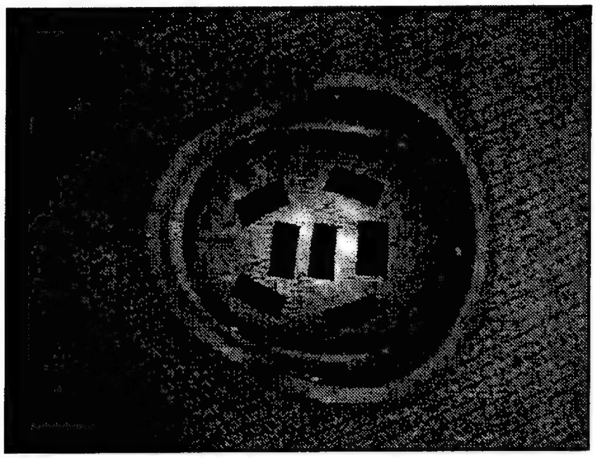


Figure 1. Hook and loop material inside PASGT shell.

Step 2. Install the retention strap (Figure 2). The rearmost hole in the helmet shell is used to affix the rear tab of the retention system. The threaded shaft of the T-nut (Figure 3) is passed through the rear tab of the retention system then, from the inside surface, through the rearmost hole of the PASGT shell. The 5/8" locking screw (Figure 3) then is placed into the rearmost hole of the helmet from the outside surface and then threaded into the shaft of the T-nut (Figure 4).

Figure 2. Retention strap.

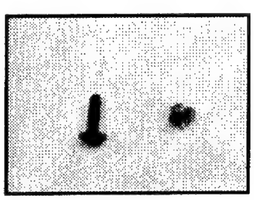


Figure 3.
5/8" Screw and T-nut.

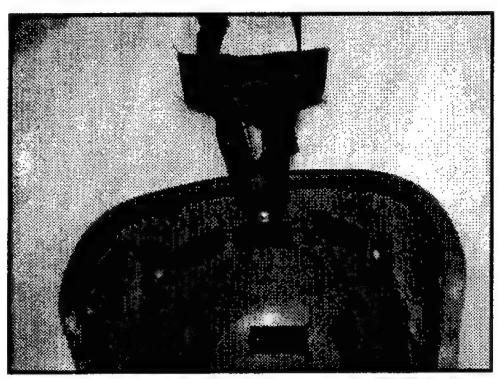


Figure 4. Attachment at rear.

At the wearer's forward sides of the PASGT helmet (Figure 5) two T-nuts and 5/8" locking screws (one set for each forward side) will be used in the same fashion with the exception that the shaft of the T-nut will be passed through the hole in the forward attachment point (there are two, choose the best one based upon the wearer's head/face size) of the retention system and then through the inside of the helmet shell (Figure 6). The screws will be passed from the outside of the shell, through the forward side holes and into the threaded shafts of the T-nuts.

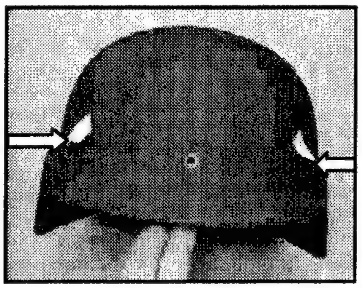


Figure 5. Forward helmet attachment points.

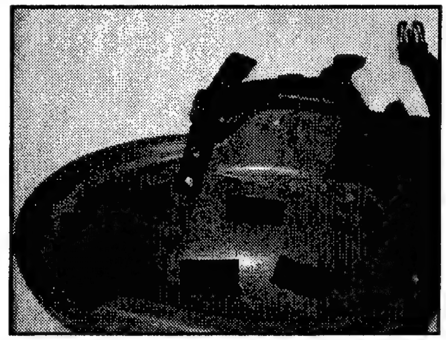


Figure 6. Attachment at front.

Step 3. The camouflage helmet cover is placed on the helmet shell with the two slotted holes in the edge of the cover at the rear of the PASGT shell. Two additional slotted holes in the edge of the cover will be located, (one on either side) at the sides of the PASGT shell (Figure 7). The hook and loop tabs on the camouflage cover are affixed to the Velcro™ material on the inside surface of the helmet shell. At the rear of the camouflage cover, the straps of the harness will have to be unbuckled and passed through the appropriate slot in the rear of the helmet cover and then be refastened. Ensure the strap is not twisted.

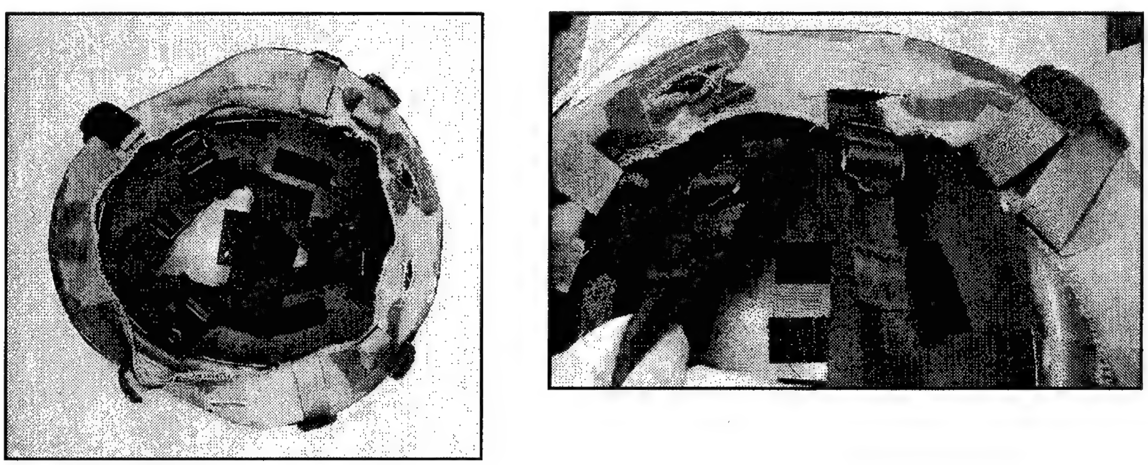


Figure 7. Attachment of cover.

Step 4. Place the crown pad (Figure 8) in the inside surface of the top of the PASGT helmet shell (Figure 9). The covering on all of the pads is designed so it will only adhere to the

Velcro™ material on one side of the pad; ensure the side that adheres is in contact with the Velcro™ material on the inside surface of the helmet.

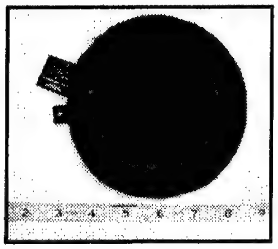


Figure 8. Crown pad.

Figure 9. Crown pad positioning.

Step 5. Place one oval pad (Figure 10) in the inside surface of the rear of the helmet just below the crown pad (Figure 11).

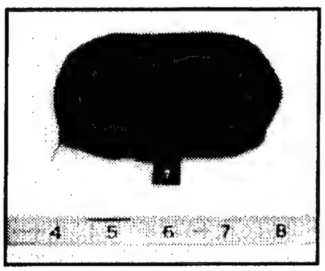


Figure 10. Oval pad.

Figure 11. Positioning oval pad below crown pad.

Step 6. Place two trapezoidal pads (Figure 12) in the rear of the PASGT shell (Figure 13). Place a trapezoidal pad in the front inside surface of the PASGT shell (Figure 14). The narrower width of the trapezoidal pad goes towards the wearer's top of the inside of the helmet.

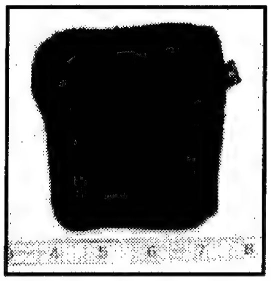


Figure 12. Trapezoidal pad.

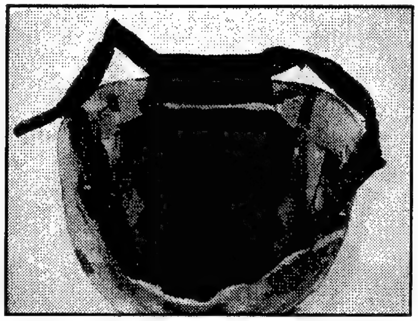


Figure 13. Positioning pads at rear.

Figure 14. Positioning pad at front.

Step 7. Place four oval pads (Figure 10), two on either side of the inside surface of the PASGT helmet shell (Figure 15). These are placed so the helmet fits well and is as comfortable as possible for the wearer.

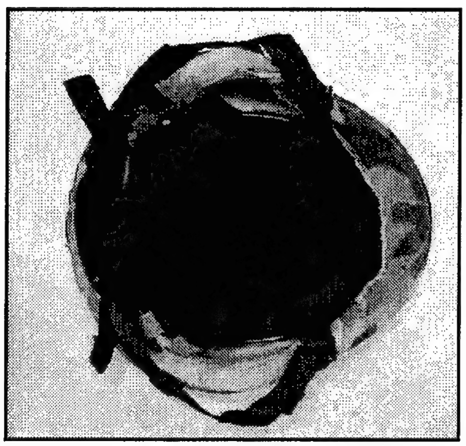
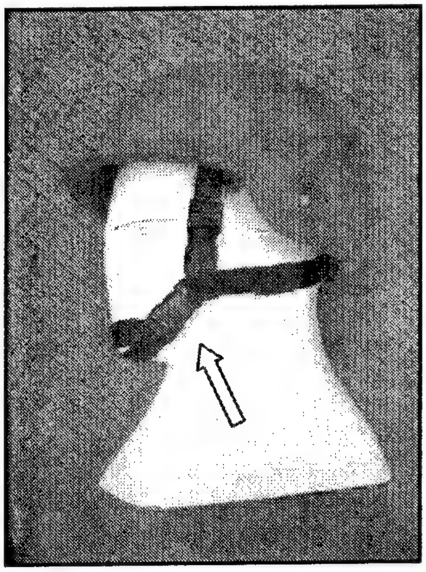


Figure 15. Positioning of oval pads.

Step 8. Place the assembled helmet on the head, pass the chinstrap with the quick release buckle around the chin and insert in open end of buckle attached to the left side retention strap (Figure 16a). Grasp the free ends of retention straps at the front and rear of both sides of the helmet and pull downward on the straps until the helmet is comfortable and snug on head (Figure 16b). After adjustment, place the free ends of the adjustment straps in elastic loops. The rear nape pad is positioned under rear adjustment buckles (Figure 17).



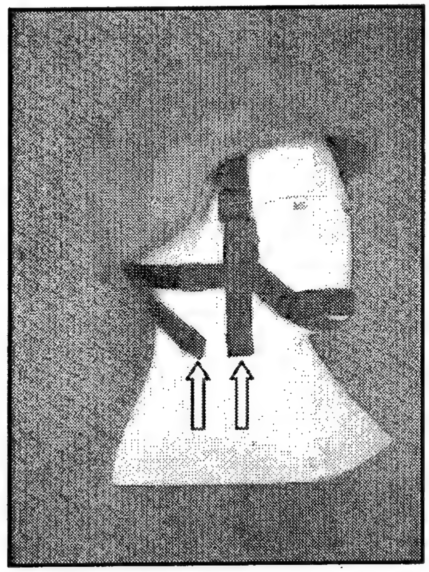


Figure 16a. Left side view showing buckle Fastened.

Figure 16b. Right side view showing adjustment straps.

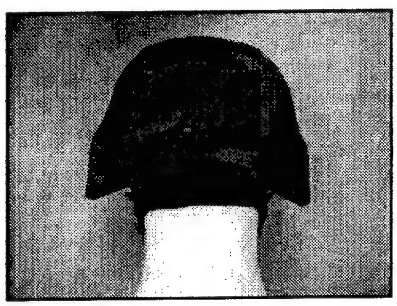
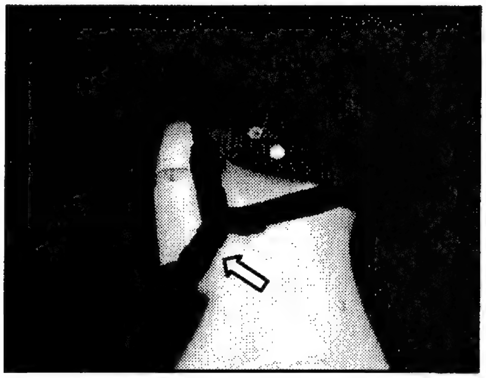


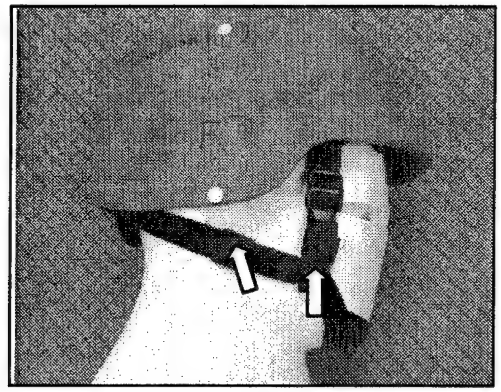
Figure 17. Rear view Nape pad under rear adjustment buckle.

Appendix I.

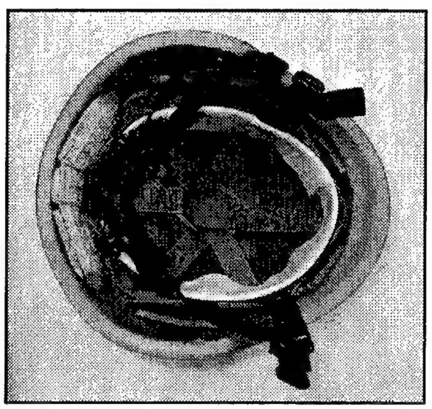
PASGT configured with Skydex® 50 mil nape pad, PIL and CGF Helmets retention strap installed.



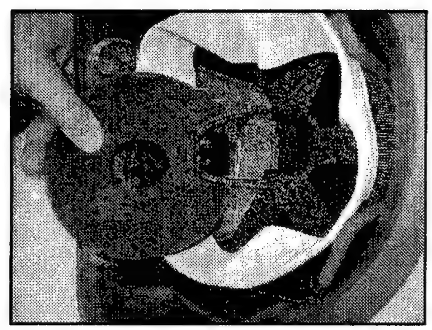
(a)



(b)



(c)

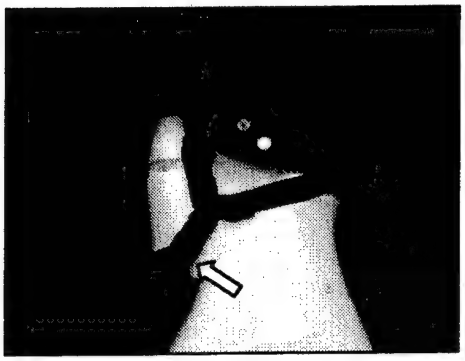


(d)

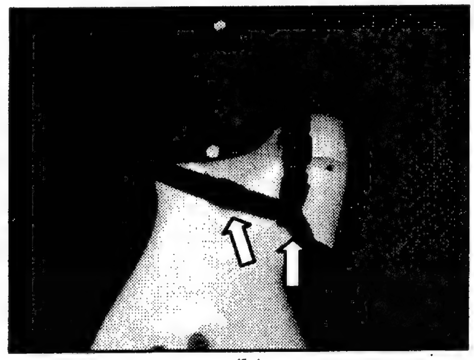
Figure I. PASGT configured with Skydex® 50 mil nape pad, PIL and CGF Helmets' retention strap installed. (a) Left side view showing quick release buckle. (b) Right side view showing adjustment straps. (c) View showing PIL, retention & nape pad. (d) Donut comfort pad installation.

Appendix J.

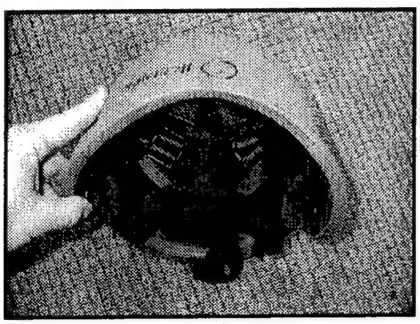
PASGT in System 3 configuration with Oregon Aero BLU pads and CGF Helmets retention strap.



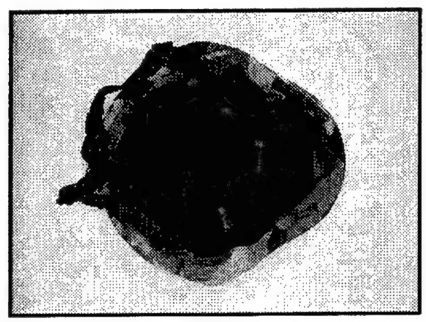
(a)



(b)



(c)



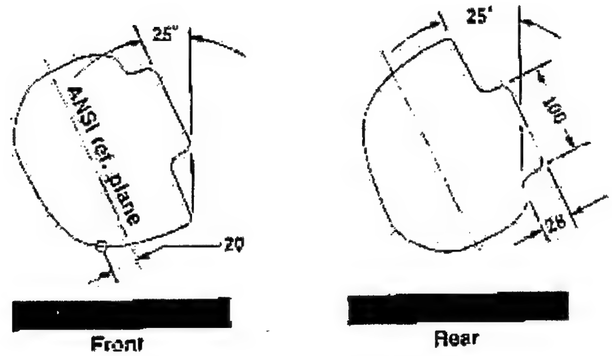
(d)

(e)

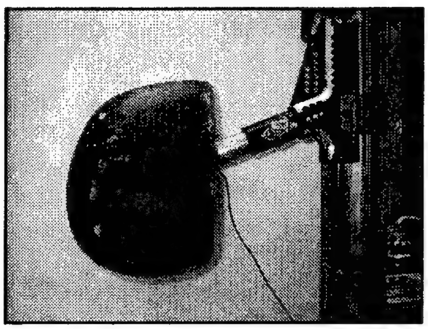
Figure J. PASGT in System 3 configuration with Oregon Aero BLU pads and CGF Helmets retention strap installed. (a) Left side view showing quick release buckle. (b) Right side view showing adjustment straps. (c) Rear view. (d) Inside view showing pad layout. (e) CGF Helmets 3 point retention harness.

Appendix K.

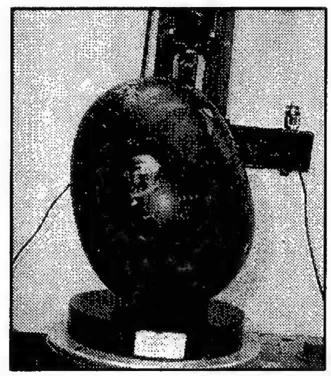
Impact locations.



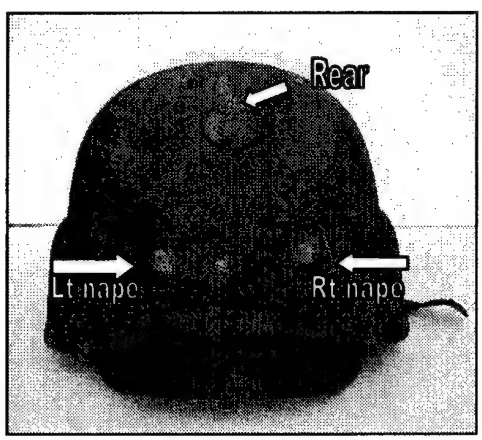
(a)



(b)



(c)



(d)

Figure K. Impact locations. (a) Front and rear headform orientations. (b) Headform 90° orientation. (c) Headform canted 20° for left nape impact. (d) PASGT showing rear, left nape and right nape impact sites.

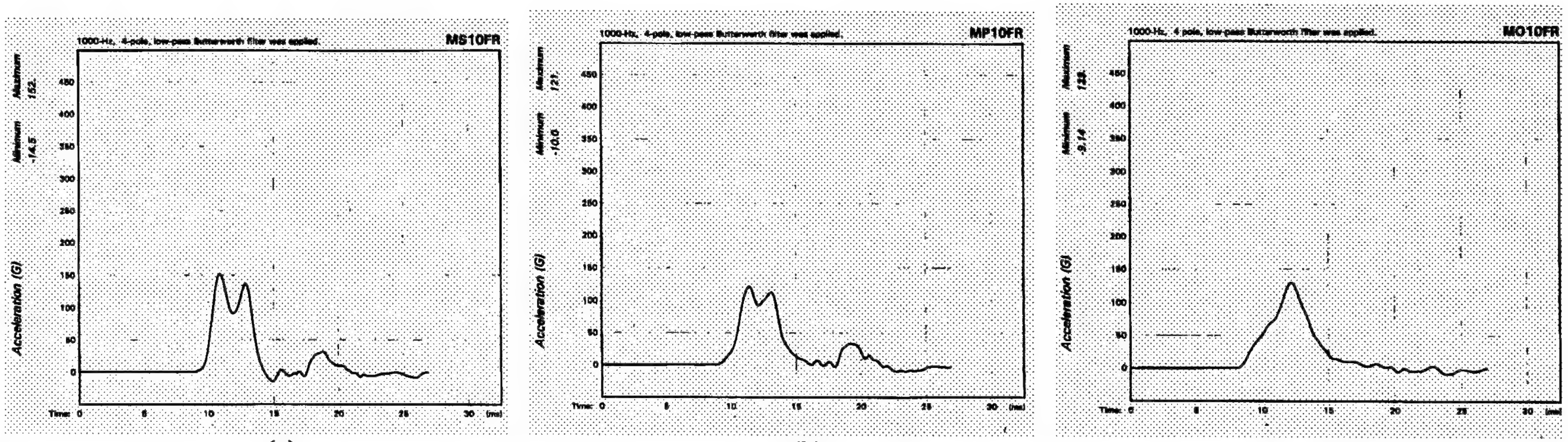
Appendix L.

National Stock Number (NSN) information.

Item	Size	NSN
PASGT Helmet	XS	8470-01-092-7525
PASGT Helmet	S	8470-01-092-7526
PASGT Helmet	M	8470-01-092-7527
PASGT Helmet	L	8470-01-092-7528
PASGT Helmet	XL	8470-01-300-3819
Woodland camouflage cover	XS/S	8415-01-092-7514
Woodland camouflage cover	M/L	8415-01-092-7515
Woodland camouflage cover	XL	8415-01-303-8945
Snow camouflage cover	XS/S	8415-01-144-1860
Snow camouflage cover	M/L	8415-01-144-1861
Desert 3 color camouflage cover	XS/S	8415-01-327-4824
Desert 3 color camouflage cover	M/L	8415-01-327-4825
Desert 3 color camouflage cover	XL	8415-01-327-4826
Headband	XS	8470-01-442-1434
Headband	S/M/L	8470-01-442-1429
Headband	XL	8470-01-442-1430
Suspension	XS	8470-01-442-2969
Suspension	S	8470-01-442-2990
Suspension	M	8470-01-442-2995
Suspension	L	8470-01-442-3001
Suspension	XL	8470-01-442-3021
Chinstrap	XS/S/M/L/XL	8470-01-092-7534
Parachutist retention harness	XS/S/M/L/XL	8470-01-092-7524
Nape pad	XS/S/M/L/XL	8470-01-092-8494
PIL	XS/S/M/L/XL	8465-01-420-4920
Donut comfort pad	XS/S/M/L/XL	8470-01-364-7074

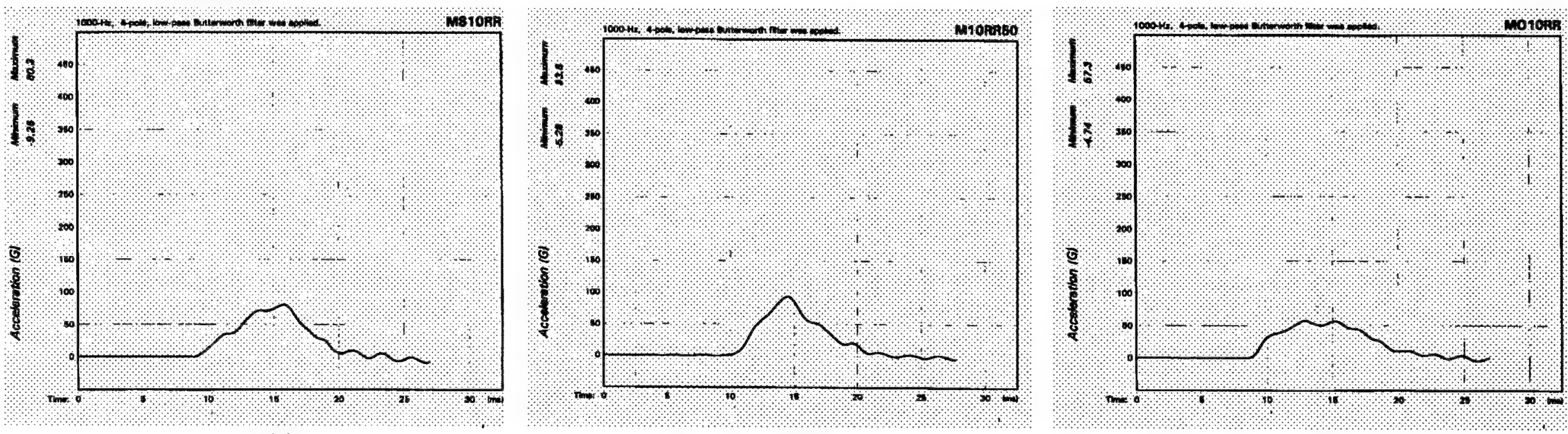
Appendix M.

Impact results from monorail drop tower.



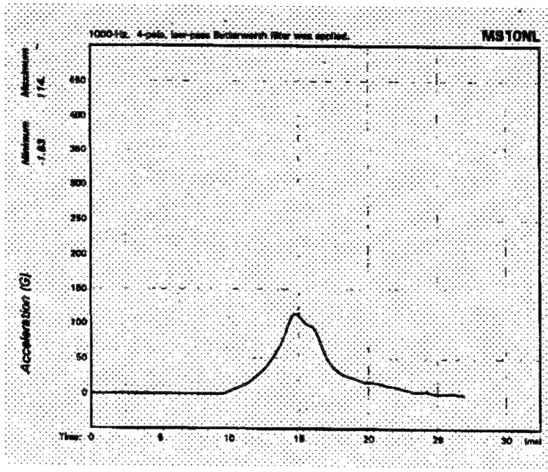
(a) (b) (c)

Figure M-1. Frontal impact, medium size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.

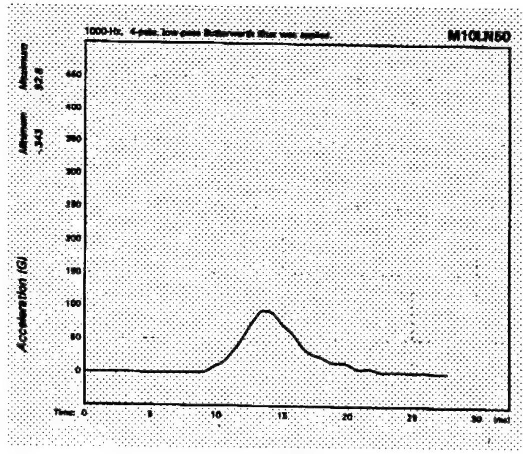


(a) (b) (c)

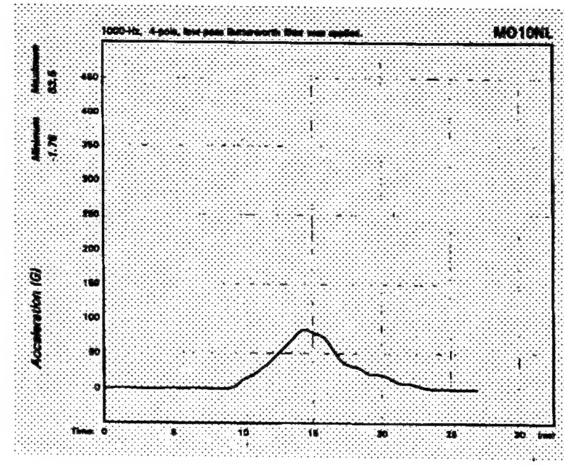
Figure M-2. Rear impact, medium size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a)

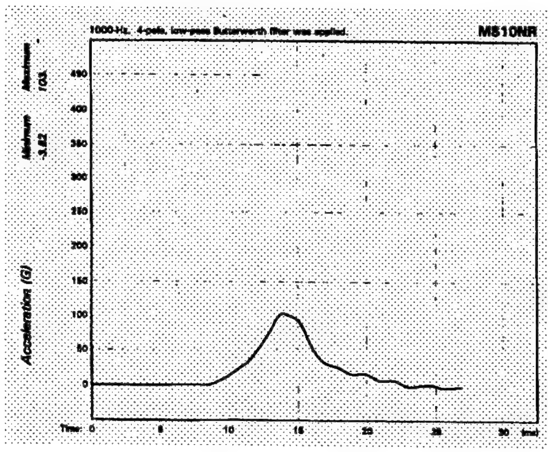


(b)

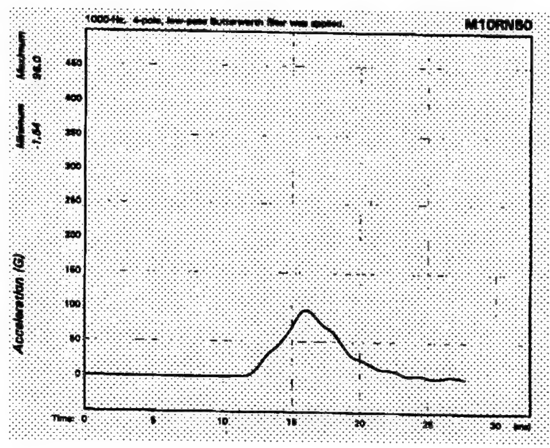


(c)

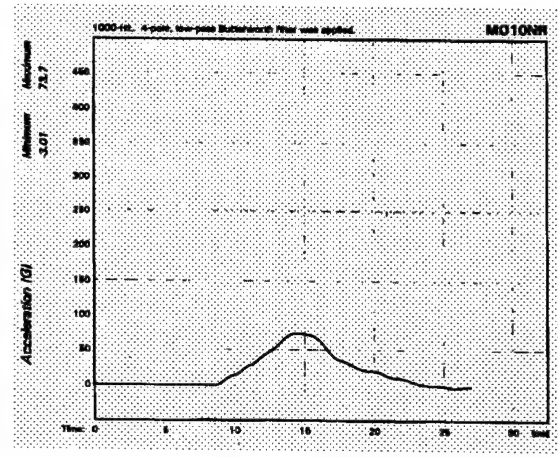
Figure M-3. Left nape impact, medium size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a)

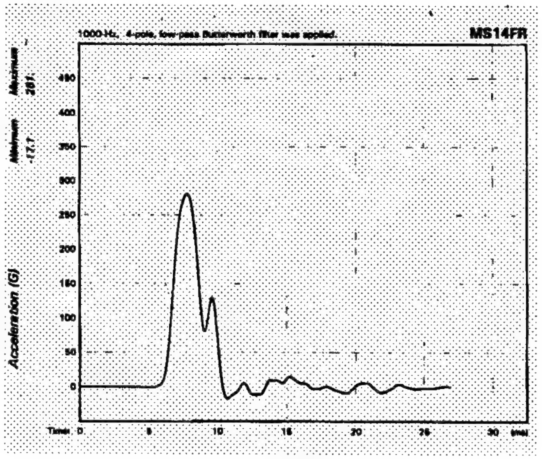


(b)

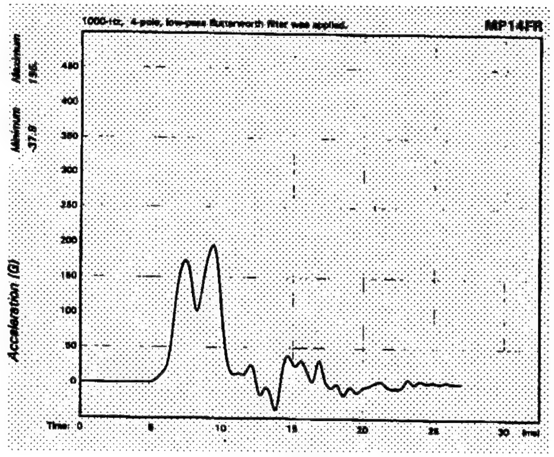


(c)

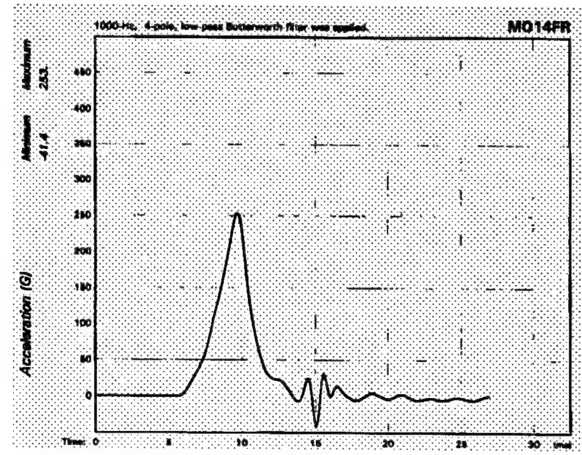
Figure M-4. Right nape impact, medium size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a)

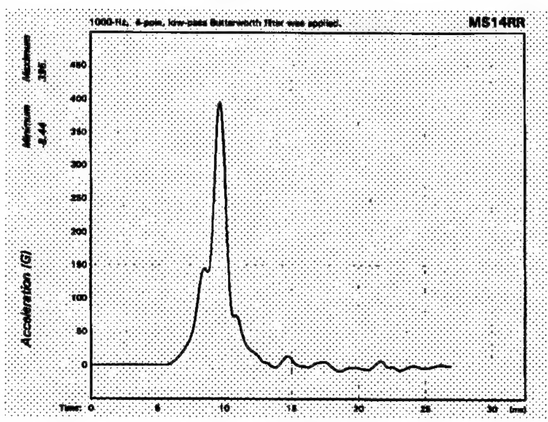


(b)

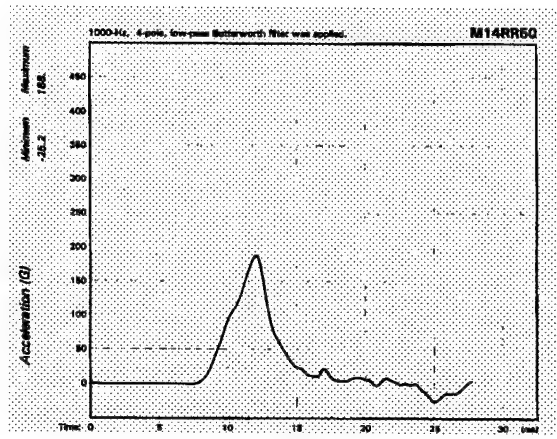


(c)

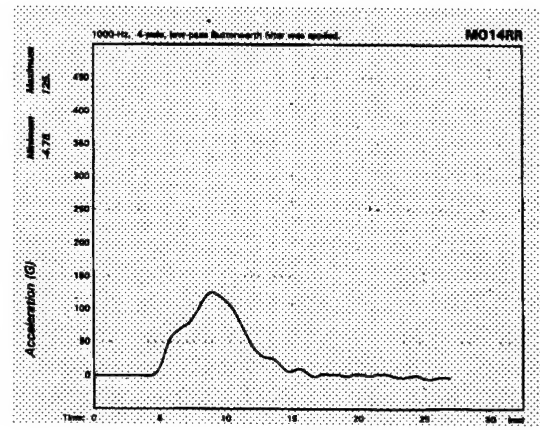
Figure M-5. Frontal impact, medium size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a)

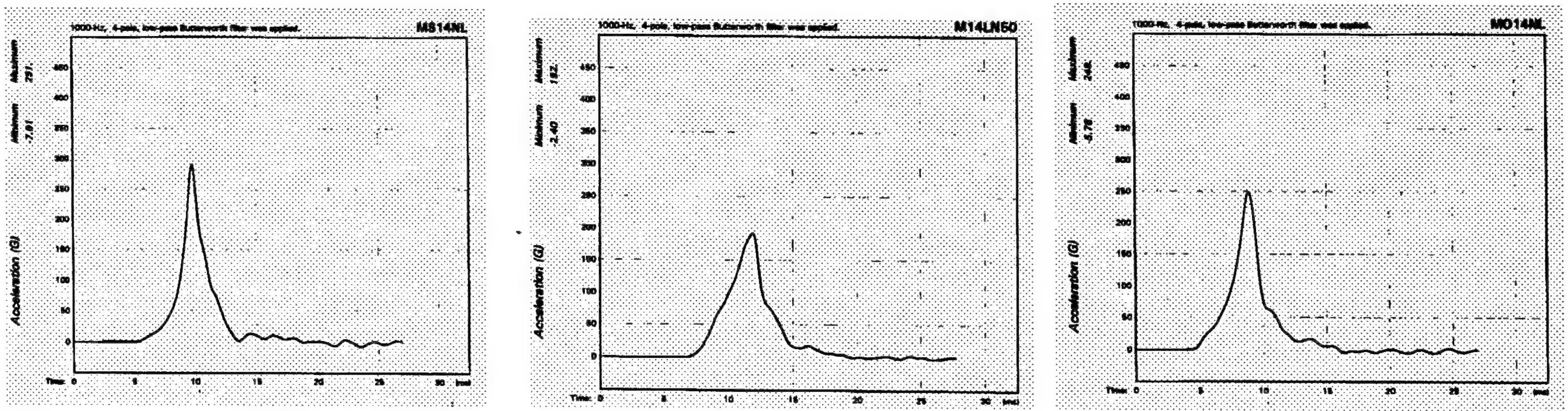


(b)



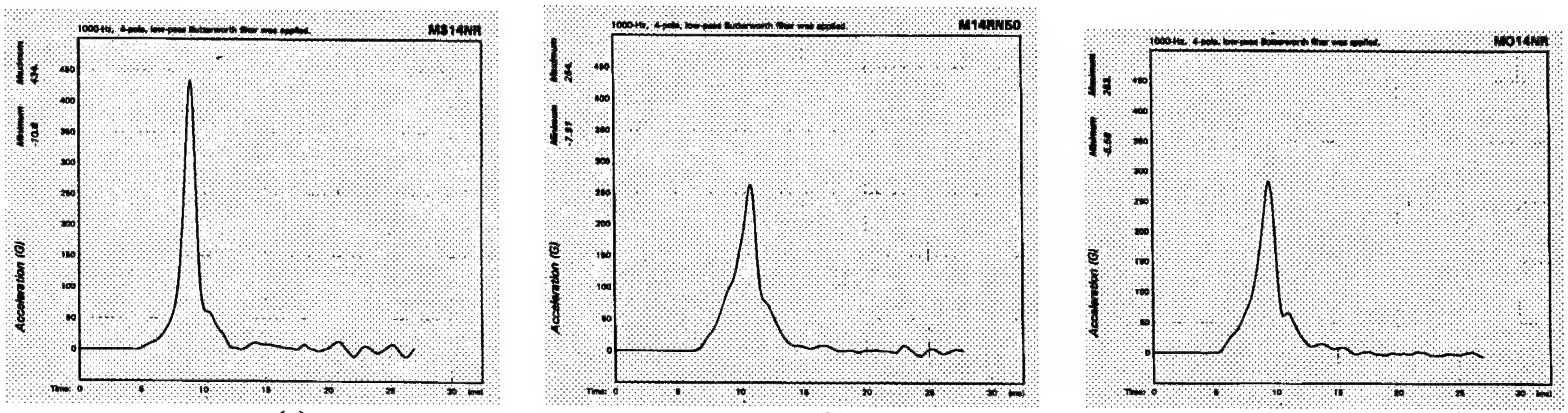
(c)

Figure M-6. Rear impact, medium size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



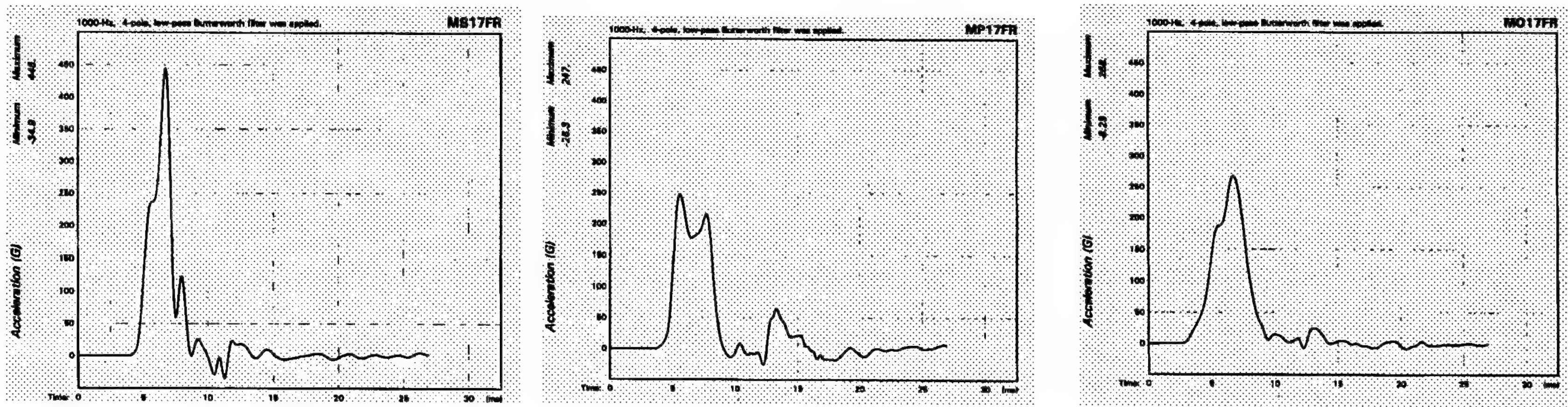
(a) (b) (c)

Figure M-7. Left nape impact, medium size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



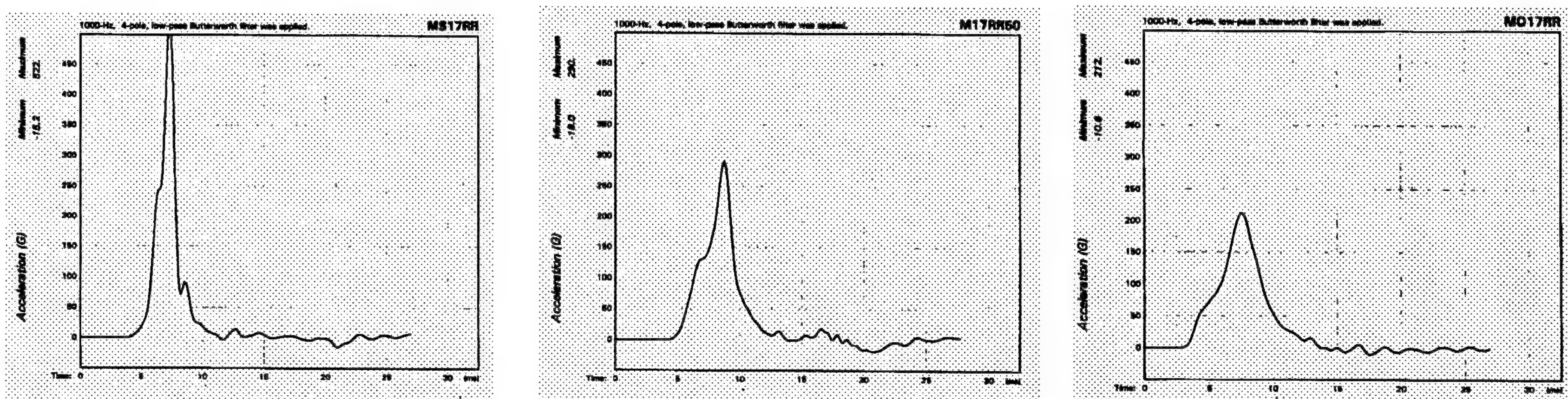
(a) (b) (c)

Figure M-8. Right nape impact, medium size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



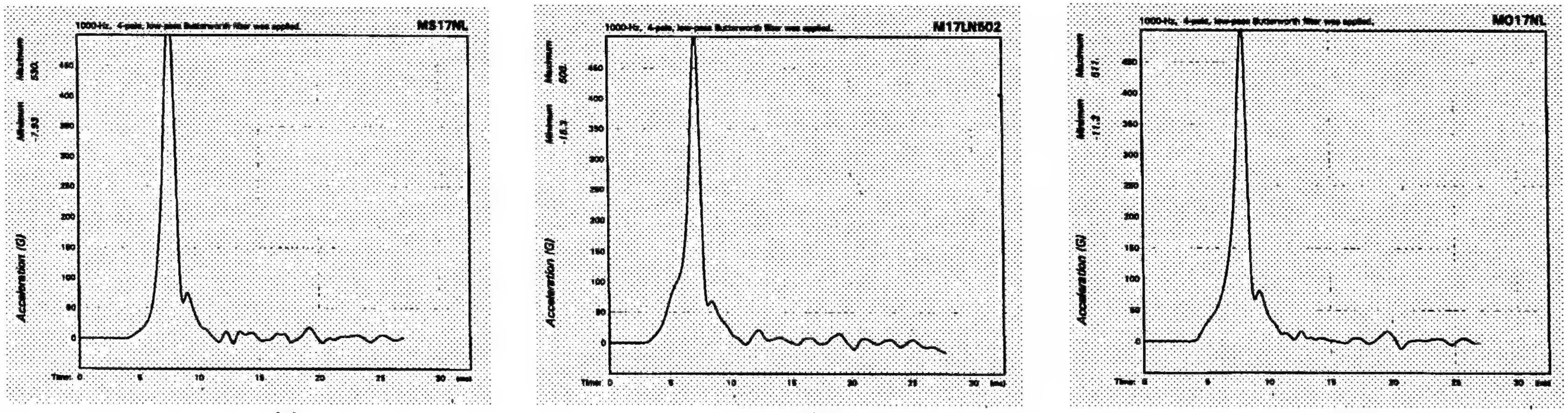
(a) (b) (c)

Figure M-9. Frontal impact, medium size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



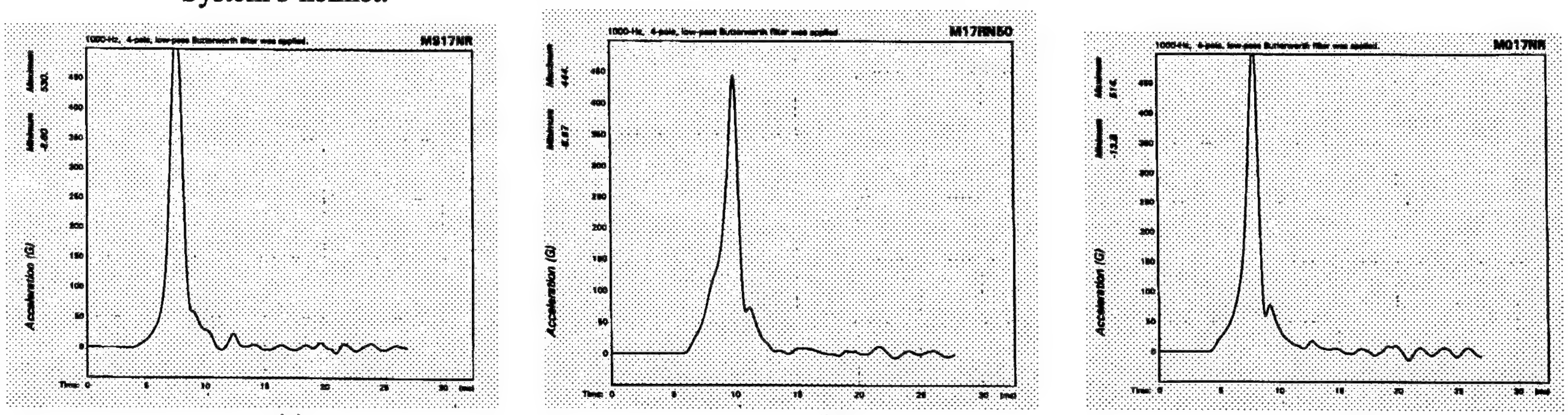
(a) (b) (c)

Figure M-10. Rear impact, medium size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



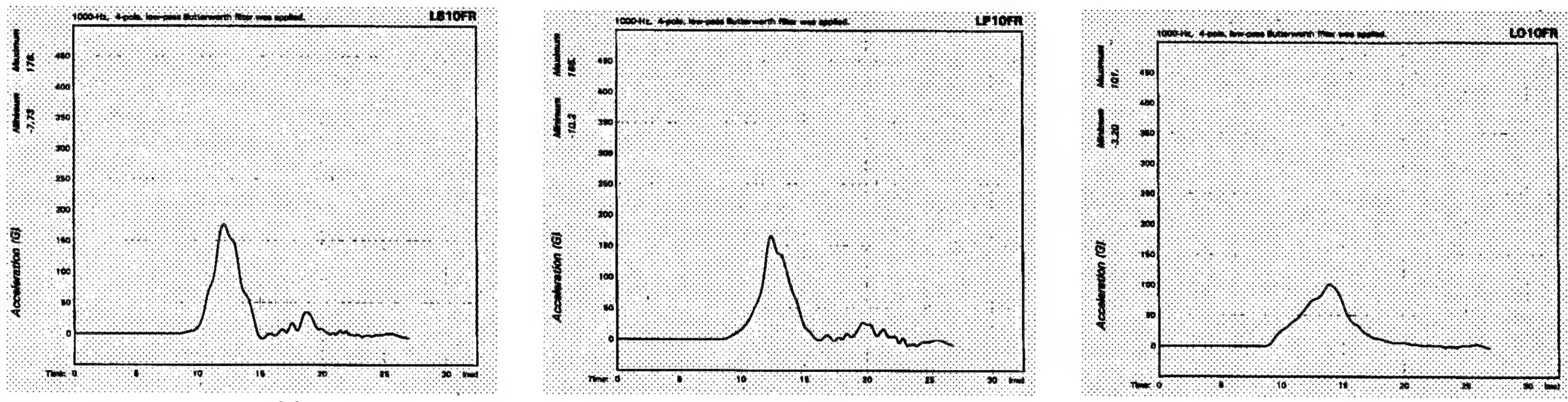
(a) (b) (c)

Figure M-11. Left nape impact, medium size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



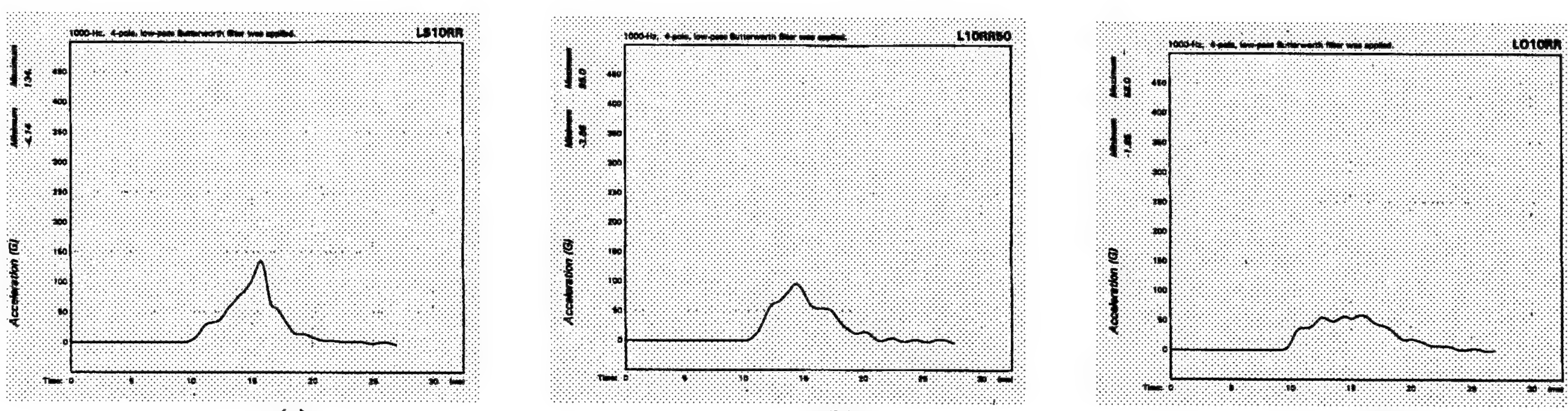
(a) (b) (c)

Figure M-12. Right nape impact, medium size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



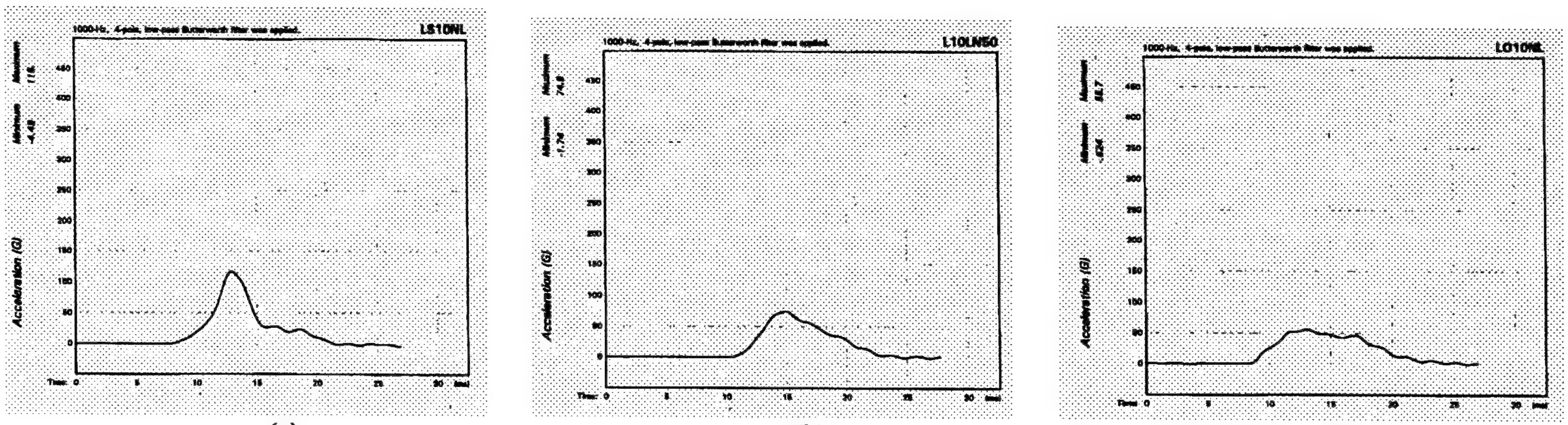
(a) (b) (c)

Figure M-13. Frontal impact, large size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



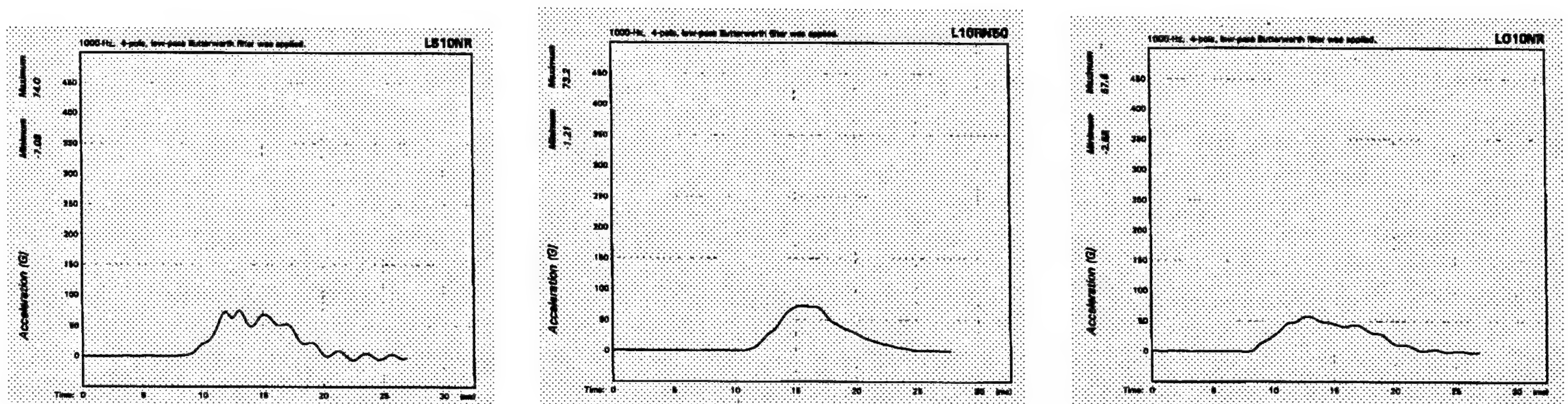
(a) (b) (c)

Figure M-14. Rear impact, large size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



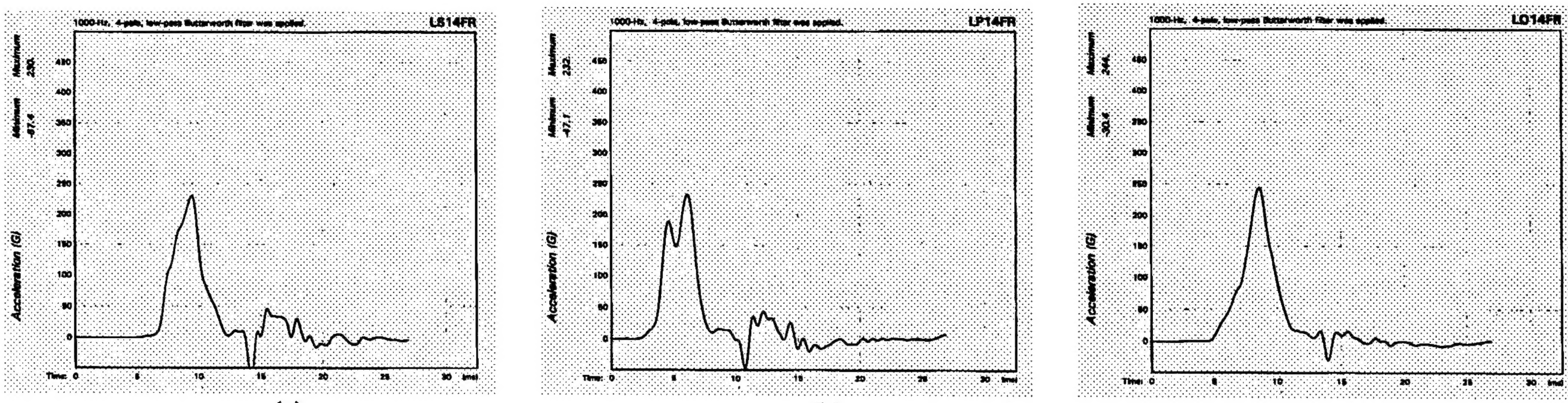
(a) (b) (c)

Figure M-15. Left nape impact, large size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



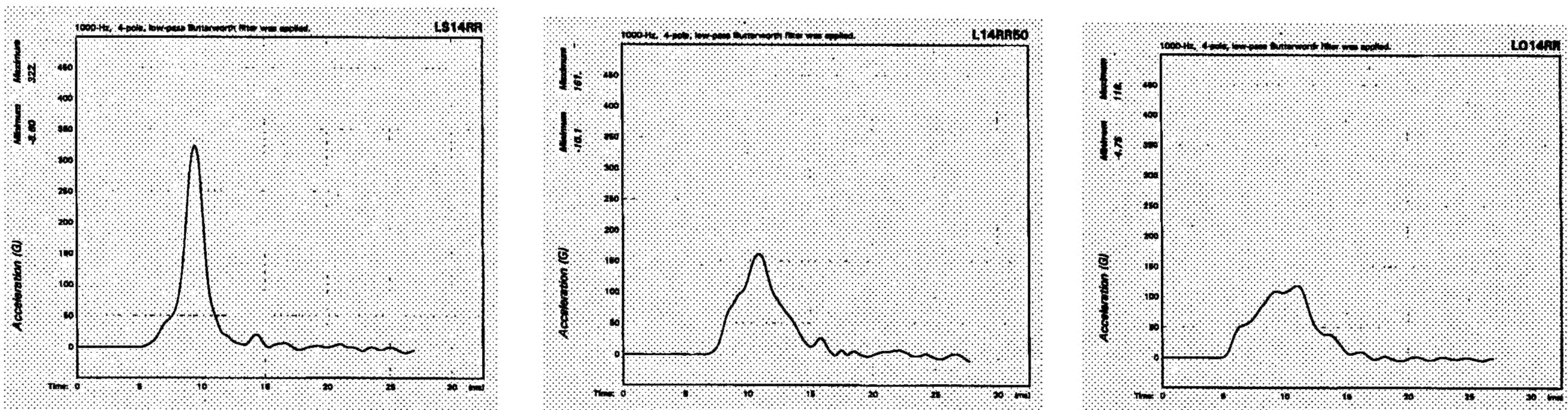
(a) (b) (c)

Figure M-16. Right nape impact, large size PASGT, 10.0 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



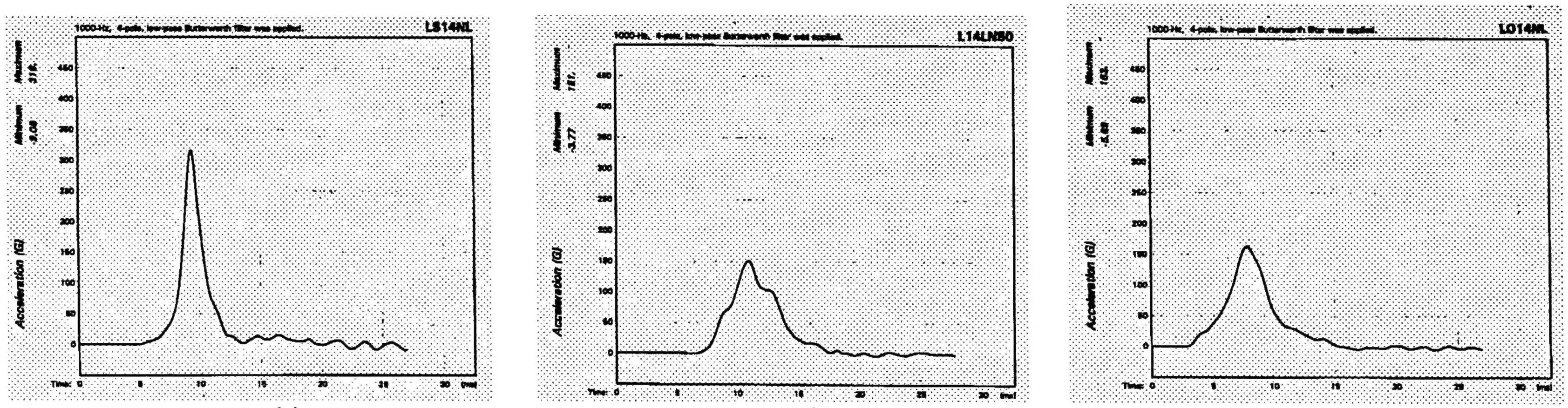
(a) (b) (c)

Figure M-17. Frontal impact, large size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



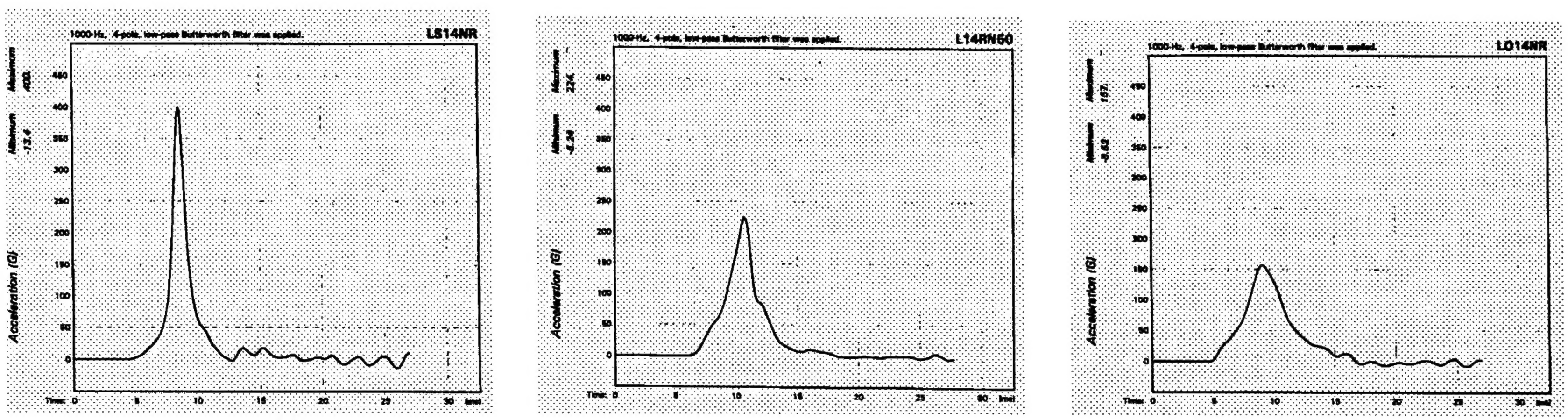
(a) (b) (c)

Figure M-18. Rear impact, large size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



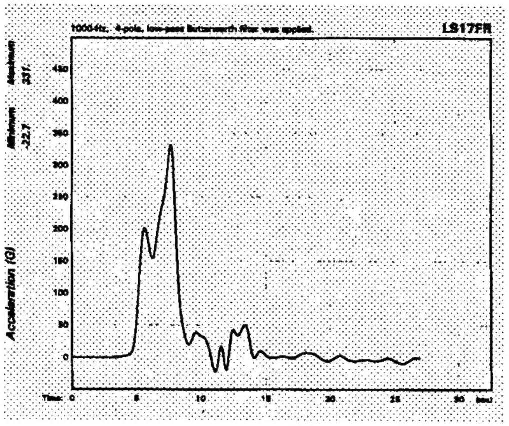
(a) (b) (c)

Figure M-19. Left nape impact, large size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.

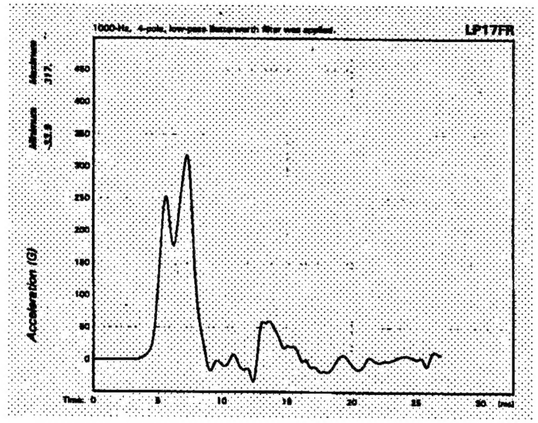


(a) (b) (c)

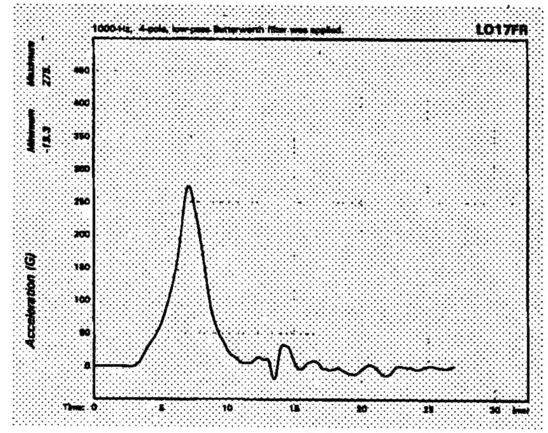
Figure M-20. Right nape impact, large size PASGT, 14.14 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a)

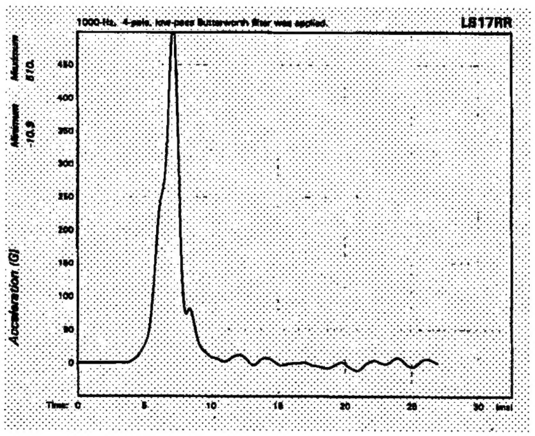


(b)

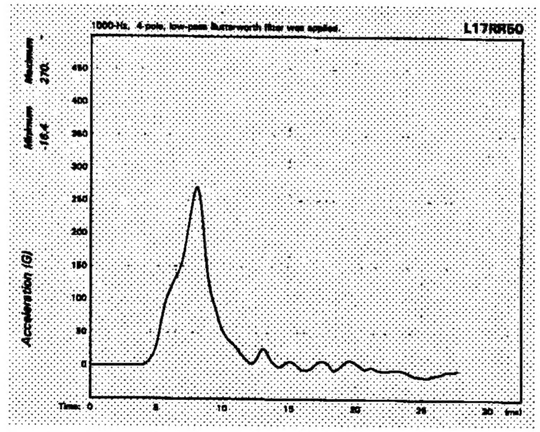


(c)

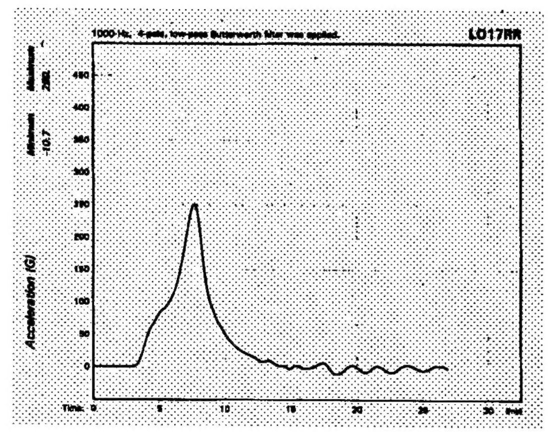
Figure M-21. Frontal impact, large size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a)

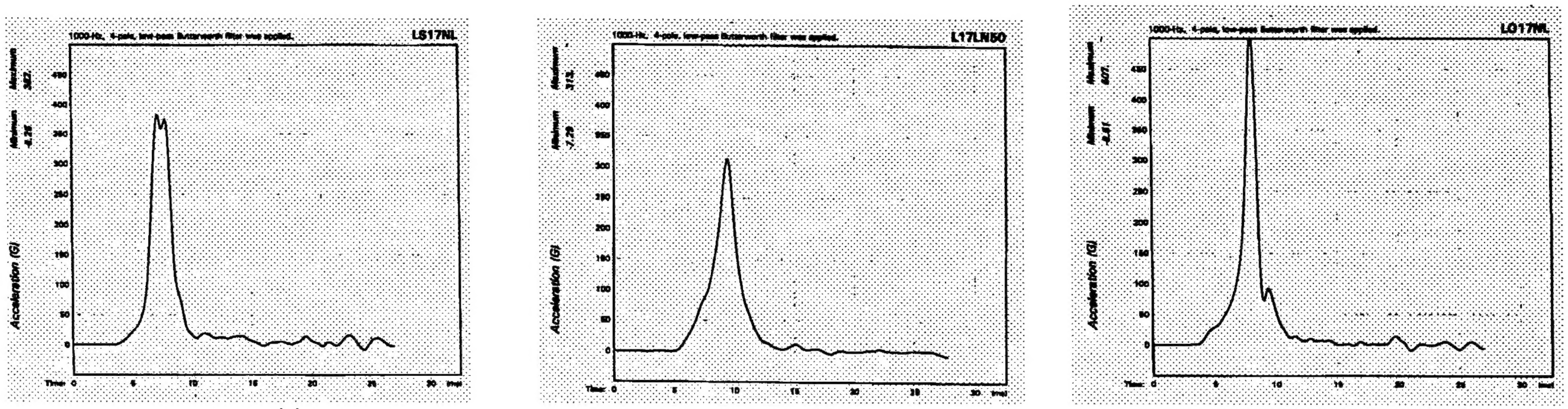


(b)



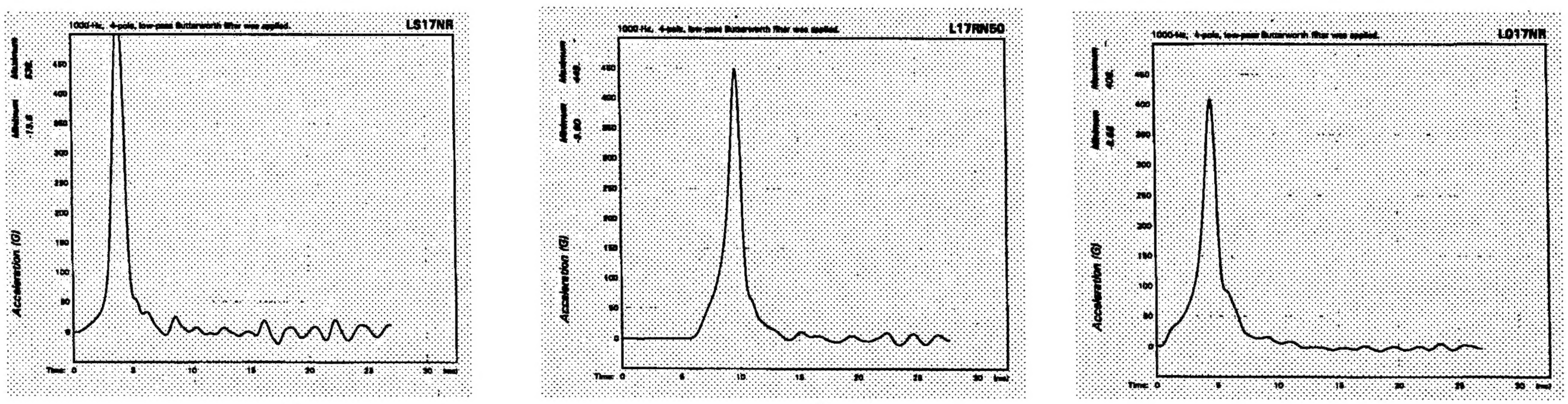
(c)

Figure M-22. Rear impact, large size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a) (b) (c)

Figure M-23. Left nape impact, large size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.



(a) (b) (c)

Figure M-24. Right nape impact, large size PASGT, 17.32 fps impact velocity. (a) System 1 helmet. (b) System 2 helmet. (c) System 3 helmet.